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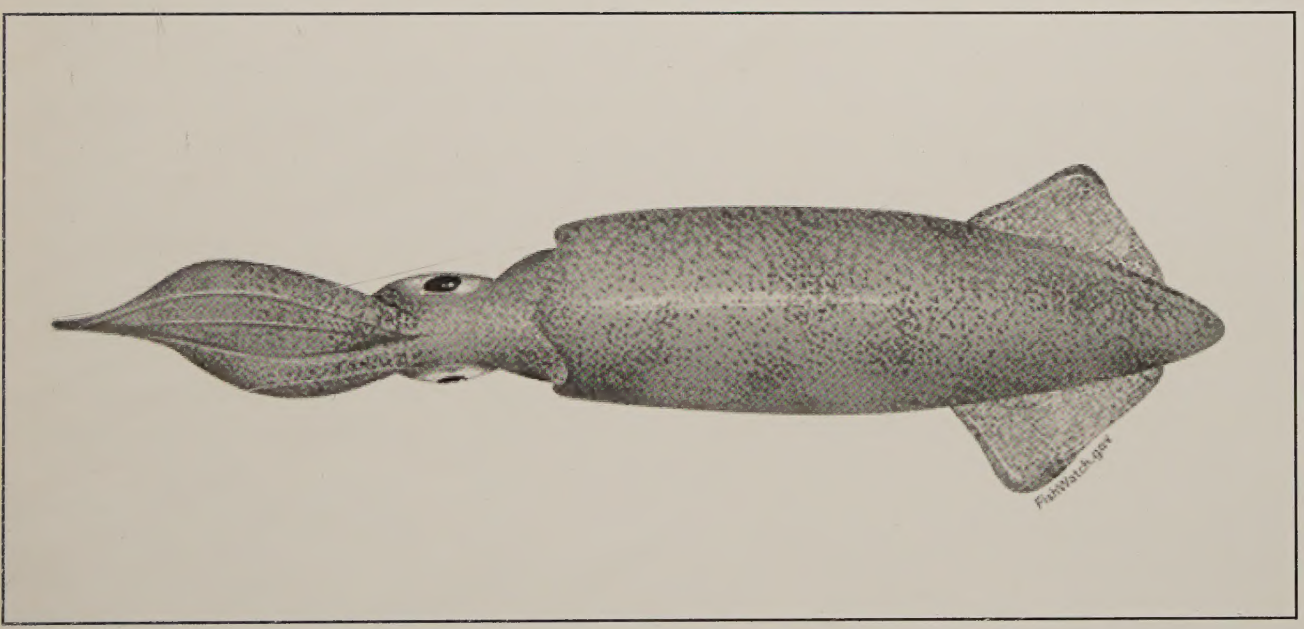

Market Squid,
Doryteuthis opalescens

Marine Fisheries REVIEW

W. L. Hobart, Editor
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On the cover:
Image of a market squid, *Doryteuthis opalescens* (NOAA/NMFS FishWatch.gov).

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North to Alaska: Spawning by Market Squid, *Doryteuthis opalescens,* in Subarctic Waters

JOHN H. EILER

North to Alaska, go north the rush is on!
(Johnny Horton, 1960's country western singer).

Introduction

Over the last several decades, changes have occurred worldwide in the physical nature of the marine environment (Duarte, 2014). In the North Pacific, this has been characterized by a general warming trend throughout the region (Litzow et al., 2020; Cheng et al., 2020). Similar to the lyrics of the song, this trend has been accompanied by the migration of a number of southern species into subarctic and Arctic waters, ranging from primary producers to apex predators (Pearcy and Schoener, 1987; Venrick et al., 1987; Mueter and Litzow, 2008; Spies et al., 2019).

Market squid, *Doryteuthis opalescens,* are a small Myopsid squid that inhabit nearshore waters along the Pacific coast of North America. Although this species has been reported from Baja California to southeast Alaska, it is most abundant in the southern portion of its range (from Baja to central California) and is an important commercial species in fisheries along the California coast (CDFG, 2005; Zeidberg et al., 2006). Market squid are also prey for many predators, including various fish, sea birds, and marine mammals. Spawning typically extends into southern British Columbia (Vojkovich, 1998; DFO, 1999; CDFG, 2005), although it has occasionally been reported in Queen Charlotte Strait in northern British Columbia (Bernard, 1980) and as far north as southeast Alaska (Wing and Mercer, 1990). In this paper, I document a recent increase in abundance and repeated spawning events by market squid in southeast Alaska and examine environmental factors that might be influential.

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Methods

Since the mid-1930's, biologists have been monitoring marine life and ocean conditions at the NMFS Little Port Walter research station in southeast Alaska (Fig. 1). Little Port Walter (LPW) is a small saltwater bay (about 1.5 km long with a maximum width of 0.4 km) that empties into southern Chatham Strait approximately 30 km from the Gulf of Alaska. The bay consists of two sections, commonly referred to as the inner and outer bay, separated by a narrow peninsula. The inner bay is characterized by a relatively flat muddy bottom with a maximum depth of 21 m. The outer bay consists of a rocky, steep-sided basin with a maximum depth of 50 m. Fresh water flows into the inner bay from Sashin Creek which drains a forested watershed of about 13 km^2, with flows ranging from 0.02 to 75.0 m^3/s (Olson and McNeil, 1967).

A variety of marine life inhabits the area. Local fishermen harvest Pacific salmon, *Oncorhynchus* spp.; halibut, *Hippoglossus stenolepis;* sablefish, *Anoplopoma fimbria*; rockfish, *Sebastes* spp.; and other marine species. Forage fish, including Pacific herring, *Clupea pallasii;* and capelin, *Mallotus villosus,* are frequently seen in nearshore waters. Various marine mammals also frequent the area, including humpback whales, *Megaptera novaeangliae;* Steller sea lions, *Eumetopias jubatus;* and harbor seals, *Phoca vitulina*. Piscivorous sea birds are often present during the summer, including double-crested cormorants, *Phala-*

ABSTRACT—Market squid, Doryteuthis opalescens, *inhabit nearshore waters along the Pacific coast of North America from Baja California to southeast Alaska, with spawning typically ranging as far north as southern British Columbia. Increased numbers of market squid and successive spawning events were observed during 2015–19 in Little Port Walter, a small saltwater bay in southeast Alaska. These observations suggest a recent shift in distribution and, combined with evidence from the 1980's, suggest that spawning periodically extends into subarctic waters. The timing (mid-June to early July) was relatively compressed compared to spawning by southern populations. Water temperature during this period averaged 10.0°C and was within the lower range reported for this species during spawning. Salinity was less than normally observed, averaging 31.1 ppt. Environmental factors within the area have not changed appreciably since the late 1990's–early 2000's, suggesting that the infrequent observations of market squid and absence of spawning prior to 2015 were not related to local conditions. It is unclear whether the increased abundance and repeated spawning events by market squid over the last several years represent the development of an established population within southeast Alaska or is the result of continued immigration from areas farther south, although colder water temperatures along the outer coast during 2017–18 were probably less conducive to northerly movements by this species.*

Figure 1.—Little Port Walter located near the southern tip of Baranof Island in southeast Alaska.

crocorax auritus; yellow-billed loons, *Gavia adamsii;* and various sea ducks, Anatidae.

Year-round observations are made at the station by the research staff and visiting scientists. Environmental data on marine conditions (including water temperature, salinity, and pH) are recorded daily at a depth of 2 m from a standardized location using a multiparameter meter[1]. Daily meteorological information is also collected at the station, including air temperature and precipitation. Satellite-based sea surface temperature data (source: NOAA Coral Reef Watch Program) were accessed via the NOAA CoastWatch West Coast Node ERDDAP server[2] and used to assess temperature patterns off the coast of southeast Alaska. Average daily temperatures during 1986–2019 were compiled for coastal waters near the entrance to Chatham Strait (from lat. 55.8°N, long. -135°W to lat. 55.5°N, long. -136°W), and averaged for each year.

Pacific salmon and other marine fish are caught during the summer using various capture methods. Since the late 1980's, a floating fish trap (similar to the type described by Hipkins, 1968) has been deployed in the inner bay and used as the primary method for capturing adult Chinook salmon, *O. tshawytscha,* returning to a research hatchery at the station. The trap, a series of mesh enclosures (outer heart, inner heart, and pot) ranging in size from 12 m x 12 m to 6 m x 6 m with a depth of 6 m and 2.5 cm square mesh, is attached to the station's floating walkway (which runs parallel to the shoreline). A mesh lead (45 m long) extends from the entrance of the trap to the shore. Fish that encounter the lead, follow it into the trap and congregate in the pot where they are crowded together and removed. The trap is monitored daily (more frequently when large numbers of fish are present) from early June to late August, and removed in early September. In addition to specific research projects, the presence of predators and atypical marine life observed within LPW are recorded year round.

Results

Over the years, small numbers of market squid have been sporadically

[1]Model Professional Plus, YSI, Yellow Springs, OH. Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[2]https://coastwatch.pfeg.noaa.gov/erddap/griddap/NOAA_DHW.html.

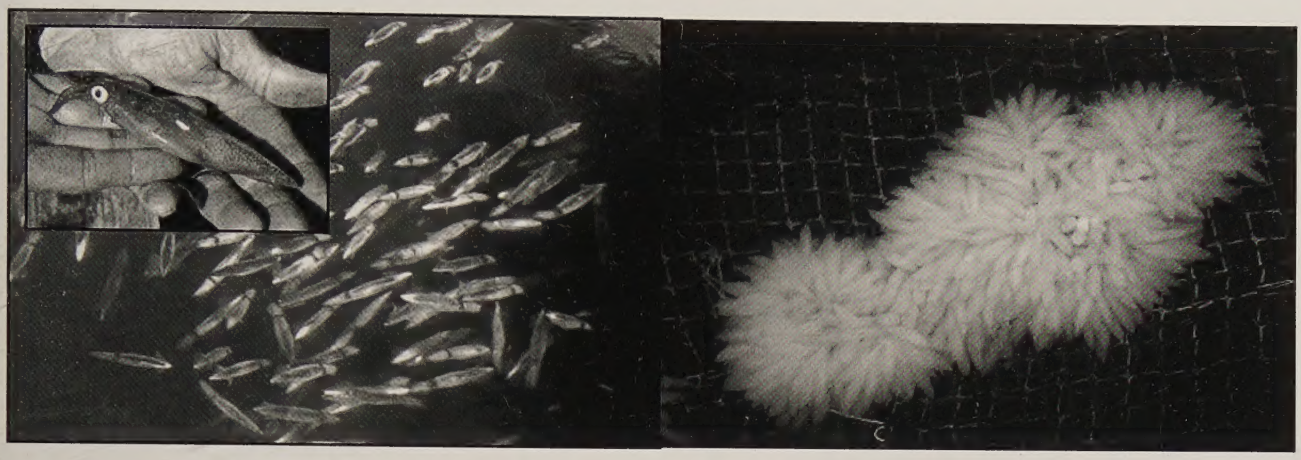

Figure 2.—Market squid and squid egg cases observed during 2015–19 in Little Port Walter, southeast Alaska.

reported in LPW. A significant change occurred in 2015 when I observed several hundred squid swimming in and out of the fish trap. The squid moved freely through the mesh netting of the trap, making it impossible to capture and enumerate the entire school. Long-handled dip nets were used to collect a small sample for identification purposes. In addition to the substantial increase in numbers, the squid were also laying clusters of egg cases on the netting of the trap (Fig. 2). Schools of market squid and subsequent spawning events (based on the presence of egg cases) were observed during 2016–19. Most of the squid were present from mid-June to mid-July, with scattered individuals recorded as late as mid-August.

Although I did not directly observe squid spawning, egg cases were laid from mid-June (as early as June 16 in 2015) to early July (as late as July 4 in 2019). Four to six clusters were observed annually, ranging in depth from ~ 2–4 m. Neither squid nor evidence of spawning were observed during the fall and spring even though research activities continued and mesh holding pens (6 m x 6 m x 6 m) were being used in the inner bay. Hatching was not observed during the study and no paralarvae were seen, although plankton blooms during the summer limit visibility and no additional sampling (e.g., plankton tows) was conducted. Several egg cases, examined when the fish trap was disassembled in the fall, were covered with algae and had not hatched.

Environmental data on marine conditions in LPW collected ~ 50 m from the fish trap showed that saltwater temperatures from mid-June to mid-July averaged 10.0°C (SD = 0.3°C) during 2015–19 and displayed a similar seasonal pattern (Fig. 3). Comparable patterns were observed during 1998–2014 (Fig. 4), with temperatures averaging 9.9°C (SD = 0.5°C). Annual mean temperatures during 1998–2019 were similar among years, averaging 7.7°C (SD = 0.4°C). Conversely, annual mean sea surface temperatures off the outer coast of southeast Alaska during 1986–2019 were more variable, with notable increases during 2004–05 and 2015–16 (Fig. 5).

Minimal differences were also observed for the other environmental data collected at the station. Salinity during June and July averaged 31.1 parts per thousand (ppt) (SD = 0.6 ppt) during 2016–19 (Fig. 6). Information was not available for this period during 2015, but salinity during late July and August was similar to subsequent years. Although limited pH data are available, levels from mid-June to mid-July averaged 8.0 (SD = 0.6) during 2014–19.

Discussion

Although market squid have been previously reported in southeast Alaska, the increased numbers and successive spawning events observed in LPW over the last several years indicate a northerly shift in distribution and, combined with other evidence, suggests that spawning periodically extends into subarctic waters, likely triggered by changing conditions in the marine environment.

Major changes have occurred in the North Pacific over the last 50 years, including periodic El Niño and La Niña events, decadal regime shifts, and irregular inter-annual variation in marine conditions (Mantua et al., 1997; Portner, 2008; Peterson et al., 2015). During late 2013, a large, unprecedented mass of anomalously warm water (commonly referred to as the Blob) began forming in the North Pacific. This formation, sustained by an El Niño event during 2015–16, dominated much of the Gulf of Alaska over the next several years, with temperatures in some areas greater than 3°C above long-term averages (Peterson et al., 2015; Tseng et al., 2017).

Although these events did not appear to influence marine conditions in LPW, the influx of warm water along the outer coast may have prompted the northward migration of market squid by creating a thermally-acceptable avenue into southeast Alaska. Market squid began appearing in surface trawls along the outer coast dur-

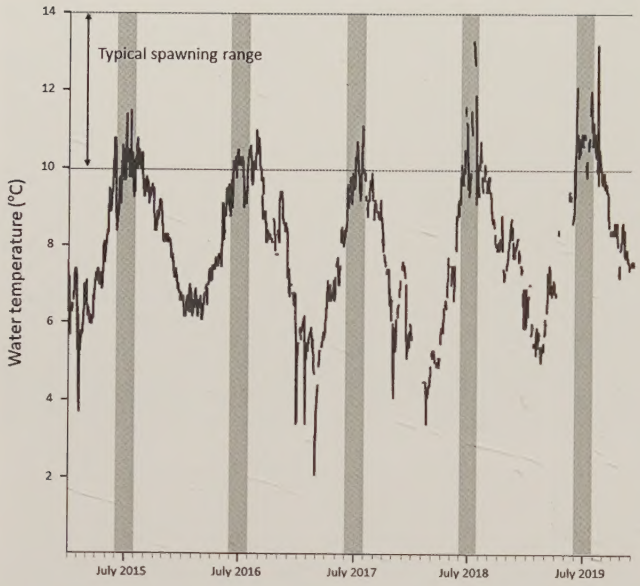

Figure 3.—Daily saltwater temperatures during 2015–2019 in Little Port Walter, southeast Alaska. The monthly periods when market squid were observed (shaded gray) and the typical temperature range associated with spawning by this species (Zeidberg et al., 2011) are shown.

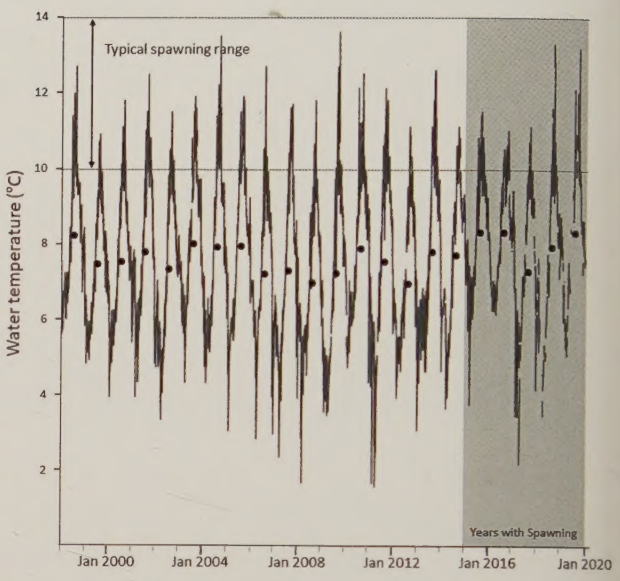

Figure 4.—Daily saltwater temperatures during 1998–2019 in Little Port Walter, southeast Alaska. Annual mean temperatures (black dots) are also shown. The years when market squid were observed (shaded gray) and the typical temperature range associated with spawning by this species (Zeidberg et al., 2011) are indicated.

ing 2016 and 2017 (Moss[3]). Although small numbers of market squid have been sporadically observed in bottom trawl surveys as far west as the Shumagin Islands, several hundred were captured off the coast of southeast Alaska during 2017 (AFSC, 2020). Local fishermen in southeast Alaska have also reported catching increased numbers of market squid in recent years (FIS, 2017; Navarro, 2018).

Similar patterns have been previously reported. Market squid were abundant in coastal waters of southeast Alaska during major El Niño events in 1957–58 and the early 1980's based on stomach contents from troll-caught salmon (Reid, 1961; Wing, 1985), with sightings observed as far north as Cross Sound (lat. 58°N). There is also evidence that spawning has previously occurred within the area. Large schools of market squid harvested off the western coast of Baranof Island during 1982 included sexually mature individuals, and several egg case clusters were reported in a small bay on Kuiu Island (Wing and Mercer, 1990), located about 40 km northeast of LPW.

Market squid spawn year-round depending on their location (Fields, 1965). Most spawning occurs from April to October in central California, and from October to May in the southern part of the state (Zeidberg et al., 2006). In southern British Columbia, spawning generally occurs between December and September, with two distinct peaks in March and July (DFO, 1999). By comparison, the timing exhibited by market squid in LPW was relatively discrete, ranging from mid-June to early July.

Based on the environmental data collected at the site, the compressed timing was likely related to water temperature. Zeidberg et al. (2011) reported that 12°C was the optimal temperature for this species, with spawning typically occurring between 10°C and 14°C; spawning was not observed in water colder than 7.5°C. Water temperatures in LPW were within this range when market squid were present and egg clusters observed (June and July), whereas temperatures from September to May were typically below this threshold.

Conversely, salinity in LPW during May–July was less than normally observed for this species, with levels within the lower range for saltwater (typically designated as 30–40 ppt, Elliot and McLusky, 2002), likely due to the infusion of fresh water from Sashin Creek. Whereas, California fishermen reported that spawning aggregations of market squid dispersed at the first sign of fresh water (Zeidberg, 2013).

Summer conditions in LPW during 2015–19 were comparable to those in 1998–2014. These similarities suggest that the sporadic observations of market squid and absence of spawning prior to 2015 were not related to local conditions.

In addition to spawning, the survival of the resulting progeny (and the related persistence of local populations)

[3]Moss, J. National Marine Fisheries Service, AFSC, Auke Bay Lab., 17109 Pt. Lena Loop Road, Juneau, AK 99801 Personal commun.

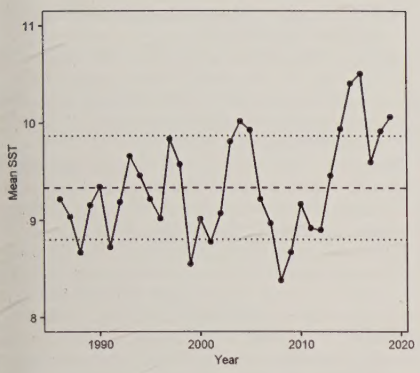

Figure 5.—Annual mean sea surface temperatures (SST) in marine waters off the coast of southeast Alaska near the mouth of Chatham Strait during 1986–2019. The horizontal dashed line represents the overall mean of the annual time series and the dotted lines represent one standard deviation around the mean.

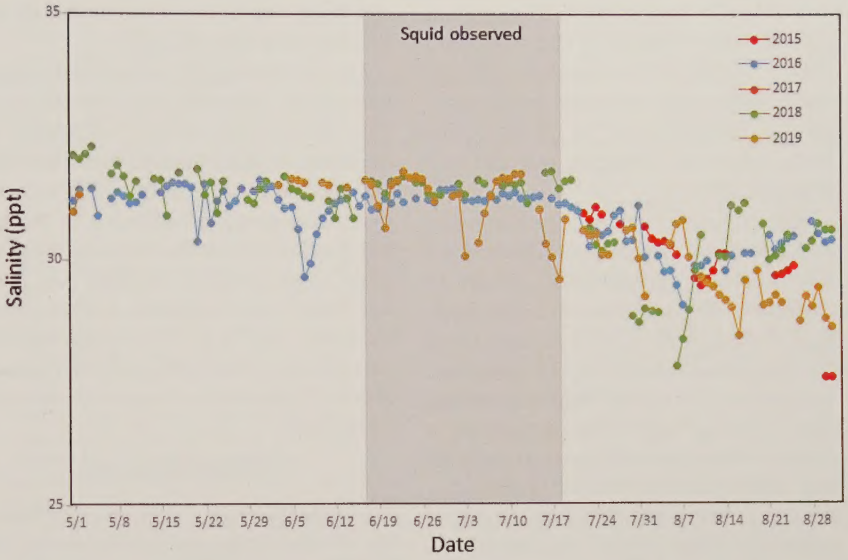

Figure 6.—Daily salinity from May through August during 2015–19 in Little Port Walter, southeast Alaska. The period when market squid were observed (shaded gray) is shown.

is also dependent on the conditions associated with summer foraging, juvenile growth, and overwintering. Navarro et al. (2018) reported that although the temperature range for spawning market squid in coastal areas of southern California was fairly broad (from 9.9°C to 15.5°C), egg deposition was limited to areas with high dissolved oxygen (>160 mmol kg^{-1}) and pH >7.8, and that these factors likely influenced habitat suitability. The pH levels recorded in LPW were within this range. Data are not available for dissolved oxygen; however, levels were probably suitable due to the regular wave and tidal action within the inner bay combined with the infusion of highly-oxygenated water from Sashin Creek.

It is not known whether the spawning events in LPW produced viable offspring. No juvenile life stages were seen during the study, although conditions for in situ observations were not ideal. Egg cases transported from LPW to the Auke Bay Laboratories (Juneau, Alaska) and held in 16°C water hatched and continued to develop for several months.[4] Juvenile life stages were reported in samples from Baranof Island in July and August 1982 (Wing and Mercer, 1990), suggesting that localized spawning during that year may have been successful.

After becoming sexually mature, market squid typically form large schools in sheltered bays and inlets (Macewicz et al., 2004). The squid usually congregate for up to two weeks prior to spawning, even though these aggregations are highly susceptible to predation. Spawning typically occurs at night, although some diurnal activity has been reported (Forsythe et al., 2004; Zeidberg et al., 2012). Once spawning begins, egg deposition is highly synchronous, typically occurring within 24 h (Perretti et al., 2016). Macewicz et al. (2004) estimated that squid were active on spawning grounds for less than a week with most eggs deposited during the first day. Similar patterns were observed in LPW. Schools of squid were only present for a limited time. Squid were not observed actively spawning during daylight hours, and evidence of spawning was based solely on the presence of egg case clusters, which appeared to be laid concurrently.

Market squid typically deposit egg cases on soft, sandy substrates at depths of 20–70 m (Fields, 1965; Zeidberg et al., 2012). In contrast, the bottom of the LPW inner bay is composed primarily of fine silt and organic sediment. No directed surveys were conducted within the surrounding area, and it is not known if squid were laying eggs at other sites within the bay or congregating in nearby areas.

Zeidberg et al. (2012) reported that although 90% of the clusters they located in California were on sand, egg cases were also attached to hard surfaces, and the rocky substrate of the outer bay and along the periphery of the inner bay may provide suitable sites for egg deposition. The congregation of squid around the LPW fish trap may relate to predator avoidance. Adult salmon are present in LPW from mid-June to late September, and the trap may provide structure and some measure of protective cover. On several occasions, the squid moved out of the trap (through the netting) when Chinook salmon entered and returned after the fish had been removed.

Market squid have a relatively short life span and are semelparous, dying shortly after spawning. Growth estimates based on length-frequency anal-

[4]https://www.adn.com/fishing/article/could-market-squid-become-new-southeast-fishery/2015/12/02/.

ysis initially suggested a life span of several years (Fields, 1965; Bernard, 1980). Spratt (1978) used statolith aging to refine age estimates and reported that market squid in central California spawned between one and two years of age.

However, more recent studies using this approach suggested that earlier assessments overestimated longevity (Jackson, 1998). Based on these findings, Butler et al. (1999) reported that the life span of market squid harvested in southern California fisheries ranged from 6 mo to < 250 days, suggesting a pattern of semiannual spawning. Jackson and Domeier (2003) observed a similar pattern, but they reported that maturation was highly dependent on ocean conditions. The synchronous timing of spawning in LPW (June–July) over several years suggests either a self-replicating population with individuals maturing at about one year of age, undocumented spawning within the area at other times of the year (although marine temperatures may not be suitable based on information reported by Zeidberg et al., 2011), or immigration from other areas.

It is unclear whether the repeated spawning by market squid in LPW represents the development of an established population or is the result of continued immigration from areas farther south. It has been estimated that market squid can potentially travel as much as 500 km during the course of their life (Zeidberg, 2013), suggesting that squid from populations in northern British Columbia could be continuing to move into southeast Alaska. However, market squid were observed in LPW during 2018–19 despite the demise of the Blob and the incursion of a cold water La Niña event in the Gulf of Alaska during 2017–18. Based on past information, colder temperatures along the outer coast may be less conducive to the northward movement of southern stocks. If so, the continued presence of market squid in LPW may indicate that a self-sustaining population has been established within the area. Expanded surveys and genetic sampling would be instrumental in addressing this hypothesis.

Due to the rapid turnover and short generation time exhibited by this species, annual recruitment is essential to maintain local populations. This dynamic also increases the vulnerability of market squid populations to changing conditions in the marine environment. The general absence of market squid in southeast Alaska from the early 1980's to 2015 suggests that these populations are ephemeral and reflect large-scale changes in marine conditions.

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The U.S. Fish Commission Steamer *Albatross* in the Strait of Georgia and Queen Charlotte Strait, British Columbia, Canada in June 1903

COLIN LEVINGS

Introduction

The U.S. Commission of Fish and Fisheries (U.S. Fish Commission) Steamer *Albatross* (hereafter *Albatross*) is renowned in the history of oceanography and conducted extensive research in many parts of the world. Several key papers summarize the activities of the *Albatross* and her voyages around the U.S. and Canadian coasts, South America, the Philippines, Japan, and elsewhere (Hedgpeth and Schmitt, 1945; Roppell, 2004). However, information on most of her voyages in British Columbia (B.C.), Canada, is scattered through the literature, with specific details dispersed in published scientific logs, navigation bridge logs, and annual reports of the U.S. Fish Commission or its successor, the U.S. Bureau of Fisheries. Exceptions are the paper by Wilby (1934) and mentions in the recent book by Pietsch and Orr (2019) on ichthyological findings from the ship in B.C. waters and the Salish Sea, respectively.

The *Albatross* routinely travelled through B.C. waters en route to Alaska for fisheries patrols in Alaska or oceanographic research (Johnstone, 1977). Between 1888 and 1914 the ship had at least 12 transits of the B.C. inner coast.[1] Her routing was often through the Canadian Inside Passage, from bases in Washington or California, and two of her regular ports of call were Departure Bay, near Nanaimo, and Union Bay, near Comox, for coal.

In this paper I focus on a subsample of the *Albatross*'s work in British Columbia, specifically a 1903 voyage (Fig. 1) through the Canadian Inside Passage to Alaska which began in Seattle, Wash., on 18 June. This was the first part of a transit to Alaska on a special mission ordered by U.S. President Theodore Roosevelt in 1902 to investigate Pacific salmon (*Oncorhynchus* spp.) fisheries in the Territory. For context, this fisheries mission was focused on investigations in areas of southeast Alaska, at the time though the ownership was being disputed between the United States, Great Britain, Canada, and British Columbia. The boundary was established by an International Tribunal in October 1903 (McDorman, (2009) provides details). Furthermore, the U.S. Fish Commission was representative of activities during the Progressive Era in the United States, when it was thought that science should be brought to bear on political, social, and economic problems, including the destruction of natural resources such as fisheries (Hay, 1959, cited in Jennings, 2014).

The 1903 *Albatross* expedition and the special mission was deemed to be the most important assignment ever given initiative to the U.S. Fish Commission at that time (Evening Star, 1903) and was staffed by some of the key U.S. fisheries scientists of the time such as David Starr Jordan (Shor, 2020), Barton Warren Evermann (Jennings, 1997), and Charles Henry Gilbert (Dunn, 1997). Cloudsley Louis Rutter, another prominent fisheries scientist who had worked as the Resident Naturalist on the ship, did not sail on the *Albatross* on this particular trip but served the special mission with his investigations on Kodiak Island (Jennings, 2014).

After outlining the sources of data for my description of the Strait of Georgia and Queen Charlotte Strait components of the voyage, I describe the results of the biological and oceanographic investigations and comment on how such cross-border investigations facilitated work by Canadian biologists. A concluding section deals with the legacy of the *Albatross* in B.C. waters.

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[1] Log books of the U.S. Fish Commission, 19th and 20th centuries. https://www.navalhistory.net/OW-US/Albatross/USFCS_Albatross-1900-1901.htm (accessed 18 September 2020).

ABSTRACT—The iconic research vessel U.S. Fish Commission Steamer Albatross *was a frequent visitor to the west coast of Canada as she transited the Canadian Inside Passage to patrol and oceanographic duties in Alaska. Her June 1903 sampling in the Strait of Georgia and Queen Charlotte Strait while en route for Pacific salmon (*Oncorhynchus *spp.) studies in Alaska yielded important early data on oceanographic conditions and records of fish and invertebrates. The cruise yielded some of the earliest bottom temperature data for the region, 44 fish species were obtained by beam trawl, beach seine, gill net, and hook and line, and a variety of invertebrate collections were made.* Albatross *investigations on this voyage, and others, left a legacy that established British Columbia marine biodiversity baselines and facilitated collaborations between Canadian and American biologists.*

Figure 1.—The coast of British Columbia showing sampling locations for the *Albatross* in June 1903.

The June 1903 *Albatross* Voyage Results

The Alaska Salmon Commission was headed by David Starr Jordan and Barton Warren Evermann and much of its work was conducted using the *Albatross* for the fisheries investigations in Alaska as described above. Although not specifically described in her orders from the President, the *Albatross* also conducted extensive oceanographic and biological sampling in B.C. waters on the trip.

While the preliminary report of the Commission is well described and available (Jordan and Evermann, 1904), the details of the B.C. part of the voyage to Alaska were difficult to track down. As did Hedgpeth and Schmitt (1945), I found her navigation bridge logs for June 1903 are not available. Fassett (1905) provided a description of the beam trawl and hydrographic work on the voyage, and the well-organized system of consecutively numbered station codes for the ship was extremely valuable in tracking the biological samples from trawl hauls. The detailed logs of the trawl and hydrographic work which support Fasset's (1905) data are also available in the Smithsonian Institution archives. However, Fassett (1905) only reported hydrographic (temperature, depth) and sediment data; few biological results are given, other than notes on size of the catch in the beam trawls.

While reviewing Fassett's data I noticed some anomalies in the timeline of the work. The ship arrived in Nanaimo on 19 June and worked in southern B.C. waters in the Strait of Georgia on 19 and 20 June. Then there was a gap of 5 days. After sampling in Queen Charlotte Strait on 25 June (near the north end of Vancouver Island) there was another 6 days at sea unaccounted for as the next set of data in Fassett's report was on 1 July in Puget Sound, Wash., rather than further north in British Columbia or in Alaska, as might be expected. The ship worked in Puget Sound for a few days and then headed up the Canadian Inside Passage again to Alaska without further B.C. sampling.

I resolved the missing information and completed her itinerary by studying the personal notes of Evermann, which I found archived in the California Academy of Sciences (Evermann, 1903). These notes considerably expanded our knowledge of the biological sampling from the voyage, especially shoreline work, which was not reported by Fassett (1905). As well, a newspaper article published in a Victoria newspaper (The Daily Colonist, 1903) reporting an interview with Jor-

dan in Nanaimo and an article in the Washington (D.C.) Times (Washington (D.C.) Times, 1903) helped explain why the expedition was particularly interested in sampling in the Strait of Georgia.

Nanaimo and Bowen Island, 19 and 20 June (Strait of Georgia)

Under the command of Lt. Franklin Swift, U.S.N., the *Albatross* left Seattle on the evening of 18 June en route to Alaska via the Canadian Inside Passage. The *Albatross*'s first port of call in Canada was at Nanaimo, B.C., on 19 June.

Jordan and Evermann arrived by train at 1:00 p.m. on 19 June from Victoria and joined the rest of the scientific staff who were already on the ship. The scientific staff included Jordan, Evermann, U.S. Fish Commissioners staff Alvin Burton Alexander, J. N. Wesner, and Harold C. Fassett; Harold Heath from Stanford University, an expert on molluscs; Harold Jordan, son of D. S. Jordan; and assistants.

According to the Victoria Times Colonist article Jordan was specifically interested in obtaining specimens of an unusual fish (described in the Washington Times article as a "peculiar kind of red fish") which had been reported from Nanaimo area waters by a local resident and forwarded to B.C. Provincial Museum (BCPM) naturalist John Fannin, who in turn had contacted Jordan. Jordan described the fish as *Zapora silenus* (Jordan, 1896), and it appears that considerable effort may have been directed toward obtaining more specimens.

On the afternoon of 19 June, the *Albatross* made two bottom trawls (54–97 m) and one surface trawl off Sharp Point near Nanaimo. On 20 June five trawls (32–320 m) were completed on Halibut Bank (off Cape Roger Curtis, Bowen Island) as well two surface trawls and two handline sets (20–42 m). One trawl (287–420 m) was made off Entrance Island, also near Nanaimo (Fassett, 1905). Some biological results from these stations can be gleaned from the 16 fish species records mentioned in Wilby (1934) and Evermann and Goldsborough (1907) using the station codes as a tracking system.

Jordan was unsuccessful in his hunt for *Zapora silenus* (now known as the prowfish) (The Daily Colonist, 1903) which is now known to be extremely rare in the Strait of Georgia (Pietsch and Orr, 2019). As well, this species is not listed in the records of the trip by Evermann and Goldsborough (1907). Other fish sampling was more opportunistic. On the evening of 19 June, Alexander set a gillnet (13 cm mesh) at the south side of the outer harbor. Pacific spiny dogfish, *Squalus suckleyi,* and spotted ratfish, *Hydrolagus colliei,* were found in the gillnet the following morning and coho salmon, *O. kisutch*, were also caught by trolling in the same area (Evermann and Goldsborough, 1907).

Additional biological data from the trawl hauls, for example new or rare species of invertebrates found in the mud or sand from the trawls, are scattered throughout the taxonomic literature, but some are summarized in reports from the expedition, sometimes known as the *Albatross* Alaska Salmon Commission (or Investigation) reports. As an example, Richardson (1905) of the U.S. National Museum described a species from a Halibut Bank station in her compilation of isopods from the expedition. There are numerous records in the Smithsonian Institutions' National Museum of Natural History (NMNH) of other invertebrates from the trawling (listed under specific collecting locations (e.g., Bowen Island), usually accompanied by station number).

Data on bottom sediment type and temperatures were also collected at the trawl stations. (Fassett, 1905). Sediment types at each of the three areas sampled ranged from sand to mud to rocky. Bottom temperatures were measured with state of the art Negretti and Zambra reversing thermometers. Bottom temperatures at Sharp Point ranged from 8.4°C to 8.6°C, at Halibut Bank from 8.2°C to 12.1°C, and at Entrance Island from 8.2°C to 8.7°C. Surface and air temperatures were also obtained.

On 20 June Evermann went with two small boats and six men to nearby Gabriola Island where they collected shore samples of invertebrates at sites they called Taylor Bay and Lora Bay. They met "a Rev Taylor," and Evermann noted he was "somewhat of a naturalist" and in his cabin they saw "several boxes of fossils, insects." In 1908 Reverend George W. Taylor became the first Curator of Canada's first marine station on the west coast (the Pacific Biological Station on Departure Bay, Nanaimo) and was very influential in this role and prior to that, as I describe in a later section.

This record of Taylor's work may be one of his first introductions to the *Albatross* and her biologists. Some of the material collected on Gabriola Island by Evermann was deposited in the NMNH, for example the shore crab, *Hemigrapsus nudus* (Rathbun, 1918). However, there are some anomalies in the collection dates for Rathbun (1918:291) notes *Albatross* collection dates for this species on 19 and 20 June on Gabriola Island. Evermann also apparently beach seined or shore collected fish at Gabriola Island on 20 June as eight species are reported from here in Evermann and Goldsborough (1907).

Union Bay–Comox, 21–24 June (Strait of Georgia)

The *Albatross* arrived at Union Bay, on Baynes Sound, at about 1 p.m. on 21 June after leaving Nanaimo that morning. The purpose of this stop was to load coal, and the vessel had made this port on many of her cruises up or down the Canadian Inside Passage. During their stay, Evermann and Alexander collected some land invertebrates and also went fishing on a lake Evermann called San Mateo Lake (likely the body of water now known as Langley Lake) where he caught a cutthroat trout, *Salmo clarki* (now *Oncorhynchus clarkii*) on 22 June (also mentioned in detail in Evermann and Goldsborough, 1907).

Although not mentioned in Evermann (1903), there is a record of steelhead trout, *Salmo gairdneri* from

Courtney Lake (near Union Bay, possibly Comox Lake near the close by town of Courtenay, as there has never been a lake called Courtenay Lake in the vicinity) on 22 June 1903 in Evermann and Goldsborough (1907), probably caught by another member of the expedition or perhaps a crew member. This specimen, as discussed by Evermann and Goldsborough (1907) in their general narrative about steelhead, was possibly a rainbow trout (now known as *Oncorynchus mykiss*). On 23 June Evermann (1903) reported doing a beach seine at low tide and caught "a few fish"—twelve species (includes lake-caught species) are reported in Evermann and Goldsborough (1907). There is also a record in the NMNH of a sea louse, *Argulus pugettensis* Dana, 1852, obtained from a coho salmon at Union Bay on 22 June.

Although not mentioned by Evermann, shore collections of invertebrates were made at Union Bay, notably polychaetes, which are mentioned in Moore (1908). There may have also been some shore collecting for invertebrates on nearby Denman Island as Rathbun (1918) mentions an *Albatross* collection of *Hemigrapsus nudus* from the island in June 1903—date and collector unspecified. In addition, the NMNH has a record of a collection of a hermit crab, *Pagurus hirsutiusculus* (Dana, 1851), collected on 22 June 1903 at Union Bay by the *Albatross*.

The ship left Union Bay at 10:15 a.m. on 24 June.

Fort Rupert,
25–26 June (Queen Charlotte Strait)

Early on the morning of 25 June the *Albatross* anchored in Beaver Bay, off Fort Rupert, B.C., and the adjacent Kwakiutl village of Tsaxis, about 5 km southeast of present-day Port Hardy. It is not clear why the expedition stopped at Fort Rupert, but the ship did sample there earlier in 1888. Beam trawl and hydrographic data from a station in mid-Queen Charlotte Strait in 435 m water depth are given in Townsend (1901). The crew went ashore to harvest clams for the ship's stores (four barrels were gathered; Tanner, 1889), but there is no information on any shoreline biological sampling. There is a record of clam digging in Evermann's report so perhaps clamming was also the reason on the 1903 stop on 25 June.

Evermann, Alexander, and Harold Jordan went ashore at 7:15 a.m. for beach seining and shore collecting. The *Albatross* stood out to sea and spent the day doing beam trawls and hydrographic sampling mostly in the vicinity of Round Island, about 4 km offshore. Six beam trawls were completed with a depth range of 46 m to 145 m. As well as sediment types, Fassett (1905) noted sponges at some stations. Six hydrographic stations were also conducted with bottom temperatures ranging from 7.5°C to 9.6°C.

Evermann's notes from beach sampling showed that he sampled for fish in tide pools at low tide and did four beach seines at high tide. *Salvelinus malma* (Dolly Varden) and starry flounder, *Platichthys stellatus*, were most abundant in the beach seine, and staghorn sculpins, *Leptocottus armatus,* were commonly observed in the tide pools. These fish species are associated with brackish water so the fish sampling may have been conducted near an estuary. Invertebrates commonly observed included "giant clams, little neck clams and big crabs." Evermann and Goldsborough (1907) list more complete references to the Fort Rupert fish collections and include 21 species from trawling, beach seining, and hook and line fishing.

As with the sampling in the Strait of Georgia, samples of invertebrates from trawl hauls were sent to specialists for identification. For example, Bartsch (1917) described a new species of marine snail (*Cerithiopsis (Cerithiopsis) charlottensis* Bartsch, 1917) from a station (4204, not 4205 as Bartsch lists) off Round Island at Fort Rupert. Rathbun (1918) notes an *Albatross* collection of the shore crab *Hemigrapsus oregonensis* on 25 June at Fort Rupert and Moore (1908) described polychaetes.

Evermann returned to the ship at 5:30 p.m. to be greeted by bad news. One of the *Albatross* crew was diagnosed with smallpox and the ship had to return to Port Townsend, Wash., to go into quarantine. The ship left Fort Rupert at 3:00 a.m. on 26 June arriving Port Townsend at 9 a.m. on 27 June. After working around the Port Townsend area for a few days, the *Albatross* left for Alaska again on 2 July. She anchored for the night on 3 July at Port Alexander, B.C., north of present-day Port Hardy but no sampling was conducted. Her next sampling episode was on 6 July at Boca de Quadra, near Ketchikan in southeast Alaska (Fassett, 1905).

Legacy of the 1903 Sampling in the Strait of Georgia and Queen Charlotte Strait

The detailed biological and hydrographic sampling from the *Albatross* in June 1903 was an unusually focused and specialized activity for the ship while she was in Canadian Inside Passage waters. Presumably the organizers of the cruise put this ecological work on the itinerary as an extension of the Alaskan cruise as B.C. dredging is not mentioned in the ship's work plan for the trip as described by Roppel (2004).

The stop at Nanaimo and the sampling in the Strait of Georgia seems clearly to have been directed by Jordan toward prowfish—referring to the "peculiar red fish" the Washington Times (1903) article notes "...the sound (presumably the Strait of Georgia) is to be thoroughly dredged and the fish studied." The visit to Union Bay was for coaling but enabled beach sampling and the Fort Rupert visit may have been for clamming.

Unlike the trawling and hydrography, the shoreline surveys were rather general investigations. The 1888 sampling at Fort Rupert is the only other record of *Albatross* hydrographic work in Canadian Inside Passage waters other than the 1903 voyage (see U.S. Bureau of Fisheries, 1920) so the paper by Fassett (1905) reports some unique data, especially bottom temperature records, for the ship and region. The bottom temperature data from the Strait

of Georgia are apparently not recorded in Canadian data files because existing DFO databases do not show any similar data before Tully's Strait of Georgia work in 1932 (Fisheries and Oceans Canada, 2020). Scagel and colleagues from the University of British Columbia provided temperature data from Queen Charlotte Strait in 1957, but the maximum depth sampled was only 15 m (Scagel, 1958).

The 1903 *Albatross* data are therefore probably the earliest bottom temperature records from the Strait of Georgia, as well as adding one more historical data point for Queen Charlotte Strait. While limited, and with the caveat that comparisons may be difficult because of possible technique differences, these do provide baseline information that might be relevant to present-day climate change and ocean temperature regime studies. The June 1903 cruise also provided baseline data on fish communities, at least at the presence or absence level (fish abundance/numbers do not seem to be recorded from the trawl surveys).

In all of the sampling, 44 fish species were collected. Although it appears that no new species of fish were found in the sampling, the beam trawl species records in Evermann and Goldsborough (1907) provide some of the first reports on fishes of the deeper water (>100 m) for the B.C. coast. Some were described as "ichthyological treasures" by noted Canadian fish biologist G. V Wilby a few decades later (Wilby, 1934). There were likely more new records for invertebrates than the few that I compiled in this paper, and a complete report would require more literature work.

The June 1903 shoreline sampling was more representative of the type of work conducted along the Canadian Inside Passage in previous and later *Albatross* cruises. The biologists aboard the *Albatross* likely sampled nearshore habitats on an opportunistic basis during her numerous Canadian Inside Passage trips, especially near Nanaimo (Departure Bay) and Comox (Union Bay) where the ship frequently stopped for coaling on her way up or down the coast. It usually took two or three days for coaling so there was ample time for the naturalists to collect from nearby shores.

For example, during a coaling stop in 1890 at Nanaimo, Gilbert (1896) collected the sharpnose sculpin, *Oligocottus acuticeps,* in tide pools on Departure Bay. Alexander (1893) sampled with a drag (beach) seine near Comox and "caught no fish of economic importance" and Austin H. Clark (in Pawson and Pawson, 2018) remarked that during a stop at Union Bay for coal in 1906 "people have been collecting fishes and all sorts of other things along the shore". There are numerous mentions of *Albatross* collections of invertebrates from Comox and Union Bay in the NMNH, and thus there are likely many museum records of invertebrates taken along the coast in shoreline surveys in addition to the 1903 sampling on Gabriola Island, Union Bay, and at Fort Rupert.

In summary, the scientific legacy of the 1903 cruise of the USS *Albatross* in B.C. waters is unique relative to the other collections made from the ship along the Canadian Inside Passage, especially those made near Nanaimo and Comox, which were mainly opportunistic shoreline collections of fish and invertebrates. Over and above the bottom temperature data, the contribution to our knowledge of the biodiversity in these regions is very significant when one takes into account both shoreline and deeper bottom trawl collections. All fish and invertebrate collections were valuable for specialists working in U.S. museums and elsewhere in their descriptions of new species and their variability, thus contributing to the baseline knowledge of fish and invertebrate communities of the Strait of Georgia and Queen Charlotte Strait.

These studies may have been facilitated by already established connections between some fisheries biologists in British Columbia and the American scientists who were part of the Stanford ichthyological group and associated with previous *Albatross* voyages. For instance, Californian John Pease Babcock was a fisheries advisor to the Government of British Columbia (1901–1909 and 1912–1933; Evenden, 2003)) and a colleague of Rutter (Jennings, 2014). It is likely Babcock was aware of the *Albatross* work that had been conducted during her stops in B.C. before the 1903 trip.

The 1903 voyage "experience" was therefore an additional example of the historical or cultural legacy the ship and her staff left in the region, notably in terms of the personal contacts made by scientists on the *Albatross* with Vancouver Island based biologists. Examples are the Reverend Taylor who figured significantly in development of scientific capacity of British Columbia marine biologists, specifically the establishment of the Pacific Biological Station in 1908 (Taylor, 1907; Rigby and Huntsman, 1938), and John Fannin from the B.C. Provincial Museum (BCPM, 1898).

Contacts between Taylor and scientists such as Gilbert, who was part of the Stanford University ichthyological group that included Jordan and Evermann, led to further cross border work after the cruise. For example, Taylor sent Gilbert an unidentified species of cottid from Departure Bay, which was subsequently described by Gilbert as a new species and named for Taylor (Gilbert, 1912). Additionally, the cruise had a relatively high profile in local newspapers whose reports raised public awareness of fisheries and marine ecology topics.

Contacts at these various levels of communication were a subtle but important part of the historical process or context that helped to build the critical mass of marine biology and ecology scientific expertise that we now see in British Columbia. As well, the increasing contacts at the scientific level between U.S. and Canadian fisheries biologists helped establish key international commissions such as the former International Pacific Salmon Commission and the International Pacific Halibut Commission which improved management of fisheries resources for the two countries.

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COVID-19 Impacts on Puerto Rican Small-Scale Fisheries in the First 6 Months

JUAN J. AGAR, MANOJ SHIVLANI, and DANIEL MATOS-CARABALLO

Introduction

The COVID-19 pandemic had a dramatic impact on food supply chains around the world, causing ripple effects from production to processing, marketing and distribution (FAO, 2020; NMFS, 2021). Early reports and studies relying on secondary information suggested that fisheries and aquaculture, particularly small-scale fisheries, were among the most heavily disrupted productive sectors (FAO, 2020; FAO and ECLAC, 2020; Bennett et al., 2020; Stokes et al., 2020; Bassett et al., 2021; Love et al., 2021). In Latin America and the Caribbean, 85% of the seafood consumed comes from small-scale fishing operations (FAO and ECLAC, 2020).

Because the duration and scale of demand and supply disruptions vary widely within and across fisheries and regions, the design of mitigation measures requires a timely understanding of ground conditions. In many places, the pandemic worsened pre-existing vulnerabilities to socioeconomic and environmental stressors (Bennett et al., 2020; Steenbergen et al., 2020; Campbell et al., 2021; Sunny et al., 2021). In the Commonwealth of Puerto Rico, the pandemic arrived on the heels of two major tropical storms (Hurricanes Irma and María) and an earthquake swarm, which in turn came after severe political and public debt crises. These events interacted with each other compounding the challenges faced by fishermen. The COVID-19 pandemic also threatened Puerto Rico's food security because 82% of its agricultural needs are imported; only 18% is produced locally (Ramos Segarra, 2020). Moreover, Ostolaza et al. (2021) report that food insecurity in Puerto Rico rose from 38% to 40% within the first 3 months of the pandemic.

The objective of this study was to investigate the immediate social and economic consequences of the pandemic on Puerto Rican small-scale fisheries, focusing on its impacts on fishing practices, income, and employment. The study covered the first 6 months of 2020 (January through June) because the early disruptions to seafood markets can be traced to January 2020, when the Chinese government imposed a lockdown in the city of Wuhan (White et al., 2021; Love et al., 2021; NMFS, 2021).

To understand the impacts of the pandemic, we conducted a rapid assessment between July and September 2020. Rapid assessments refer to a suite of evaluation methods and techniques used to gain information about local conditions in an expeditious and economical manner. Rapid assessments can be useful tools to document and monitor evolving ground conditions, and to inform and guide funding relief decisions. In addition, they can serve as a baseline to evaluate the impact of mitigation measures and coping strategies (Chambers, 1981; Garces et al., 2010; van Holt et

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ABSTRACT—The COVID-19 pandemic and governmental actions to contain its spread threatened the livelihoods of millions of small-scale fishermen around the world. Because the duration and scale of the impacts can vary widely within and across fisheries and regions, it is important to monitor ground conditions. This study reports on the early socioeconomic effects of COVID-19 on Puerto Rican small-scale fishermen. The study focuses on the first 6 months of 2020 since COVID-19 began to disrupt seafood markets in January 2020.

Drawing on 317 telephone interviews with fishing captains conducted between July and September 2020, we find that the pandemic severely disrupted fishing operations owing to three main factors: loss of seafood markets mainly in the leisure and hospitality sector, strict commonwealth and local governmental restrictions (lockdowns and curfews), and the adoption of sanitary control and prevention measures (face covering and social distancing requirements). These interrelated factors forced most fishermen to pause their fishing activities. Forty-three percent of the fishermen polled stopped their fishing between 1–3 months, and another 33% suspended their fishing for more than 3 months.

Preliminary self-reported fishery statistics show that landings and dockside revenues fell by 40% and 51%, respectively, in the first semester of 2020 (January–June) relative to the same period in 2019. However, the fishermen surveyed specified that their fishing revenues had declined by 65% during the same period. Fishing income shortfalls, layoffs, and the loss of non-fishing opportunities adversely impacted fishermen's livelihoods. Captains reported losing, on average, almost $6,900 relative to the first semester of 2019. One in four captains reported laying off, on average, 1 crewmember. The study also found that fishermen withstood the initial impacts of the pandemic thanks to the support of family and friends, personal savings, and social protection programs (unemployment benefits, federal stimulus checks, food stamps, etc.). Entrepreneurial fishermen were able to make ends meet by turning to online retailing and delivery and by continuing to sell roadside and house-to-house.

al., 2016; Smith et al., 2019; Smith et al., 2020).

Fishery Background

Small-scale fishermen operate around the entire archipelago, which consists of the main island of Puerto Rico and several smaller islands and cays, including Vieques, Culebra, and the fishing banks near the islands of Mona and Desecheo (Fig. 1). In 2019, Puerto Rican fishermen landed about 2.5 million pounds of finfish and shellfish worth $12.1 million in dockside revenues (NMFS[1]). Between 2015 and 2019, the west and east coasts accounted for the majority of the commonwealth's landings and dockside revenues. On average, the west coast generated 35% of landings and 36% of the revenues and the east coast generated 30% of the landings and 32% of revenues. The south coast accounted for 21% of the landings and 19% of revenues and the north accounted for the remaining 13% of the landings and revenues. The west coast is the most productive area partly because it has a relatively shallow and extended shelf. The east coast also has a large shelf area, which includes the nearby islands of Vieques and Culebra; by contrast, the north coast is the least productive coast because it has a narrow insular shelf and an exposed coast that provides little protection against rough seas which partly discourages the use of use of certain gears such as traps (Suarez-Caabro, 1979; Tonioli and Agar, 2011).

There are around 1,200 licensed fishermen but fewer than 900 (including crew) show up in fishery statistics (NMFS, 2021). Most fishing vessels are small (20 ft in length) with moderate levels of propulsion (80 hp) and mechanization (Matos-Caraballo and Agar, 2011). Fishermen mainly target spiny lobster, *Panulirus argus;* queen conch, *Strombus gigas;* reef-fish (Lutjanidae, Serranidae, Scaridae, Labridae); and other miscellaneous coastal pelagic species (Scombridae, Coryphaenidae). Between 2015 and 2019, seven species accounted for 77% of the commonwealth's dockside revenues. Spiny lobster, queen conch, silk snapper, *Lutjanus vivanus;* queen snapper, *Etelis oculatus;* yellowtail snapper, *Ocyurus chrysurus;* dolphinfish, *Coryphaena hippurus;* and lane snapper, *Lutjanus synagris,* accounted for 28%, 17%, 12%, 7%, 5%, 4%, and 3% of the revenues, respectively.

On a regional basis, the west coast derived 77% of its revenues from five species (spiny lobster, 24%; silk snapper, 18%; queen snapper, 17%; queen conch, 14%; and dolphinfish, 4%), and the east coast obtained 79% of its revenues from four species (spiny lobster, 36%; queen conch, 31%; yellowtail snapper, 7%; and silk snapper, 5%). The south coast derived 69% of its revenues from seven species (spiny lobster, 35%; queen conch, 9%; lane snapper, 8%; yellowtail snapper, 6%; silk snapper, 4%; queen snapper, 4%; and dolphinfish, 3%) and the north derived 68% of its revenues from seven species (silk snapper, 24%; dolphinfish, 13%; spiny lobster, 12%; yellowtail snapper, 10%; other snappers; 4%; queen snapper, 3%; and lane snapper, 2%).

The most common gears around the island are scuba and skin diving (including spearfishing), hook and line, fish and lobster traps, and nets (Matos-Caraballo and Agar, 2011; Tonioli and Agar, 2011; Agar et al., 2017). Between 2015 and 2019, scuba and skin diving, hook and line, and fish and lobster traps accounted for 39%, 37% and 16% of the revenues, respectively. Regionally, most of the west coast revenues originate from hook and line (49%) and scuba and skin diving (37%), whereas east coast revenues are mainly derived from scuba and skin diving (55%) and fish and lobster traps (24%). South coast revenues are mainly sourced from scuba and skin diving (32%) and fish and lobster traps (30%), while on the north coast they

[1]NMFS. 2022. Accumulated landings system (Avail. at https://www.fisheries.noaa.gov/inport/item/1905). Accessed 3 March 2022.

RESUMEN—La pandemia del COVID-19 y las medidas gubernamentales para contener su propagación amenazaron el sustento de millones de pescadores de pequeña escala en todo el mundo. Dado que la duración y escala de los impactos pueden variar considerablemente dentro y entre pesquerías y regiones, es importante hacer un seguimiento de las condiciones de campo. Este estudio describe los impactos socioeconómicos iniciales de la pandemia sobre los pescadores de pequeña escala de Puerto Rico. El estudio se enfoca en los primeros 6 meses del 2020, debido a que la pandemia comenzó a afectar los mercados de pescado y mariscos en enero del 2020.

Basándonos en 317 entrevistas telefónicas con capitanes de pesca, realizadas entre julio y septiembre del 2020, hallamos que la pandemia interrumpió severamente las operaciones de pesca debido a tres factores principales: pérdida de mercados de pescado y mariscos (principalmente en el sector de la hostelería), restricciones estrictas impuestas por los gobiernos nacionales y locales (confinamiento y toques de queda), y la adopción de medidas sanitarias de control y prevención (ordenes de cobertura facial y distanciamiento social). Estos factores interrelacionados obligaron a la mayoría de los pescadores a detener sus actividades de pesca. Cuarenta y tres por ciento de los pescadores encuestados dejaron de pescar entre 1 y 3 meses, y otro 33% suspendió su pesca por más de 3 meses.

Las estadísticas pesqueras preliminares indican que los desembarques e ingresos cayeron un 40% y un 51%, respectivamente, en el primer semestre de 2020 (enero-junio) en relación con el mismo período de 2019. Sin embargo, los pescadores encuestados especificaron que sus ingresos provenientes de la pesca habían disminuido en un 65% durante el mismo período. La disminución de los ingresos de la pesca, los despidos, y la pérdida de oportunidades laborales no relacionadas con la pesca afectaron negativamente el sustento de los pescadores. Los capitanes indicaron haber perdido, en promedio, casi $6,900 en relación con el primer semestre del 2019. Uno de cada cuatro capitanes informó haber despedido, en promedio, un miembro de la tripulación. El estudio también halló que los pescadores sobrellevaron los impactos iniciales de la pandemia gracias al apoyo de familiares y amigos, ahorros personales y programas de protección social (beneficios por desempleo, cheques de estímulo federal, cupones de alimentos, etc.). Pescadores con espíritu emprendedor lograron sobreponerse recurriendo a la venta minorist en línea con entrega, y vendiendo en la carretera y de casa en casa.

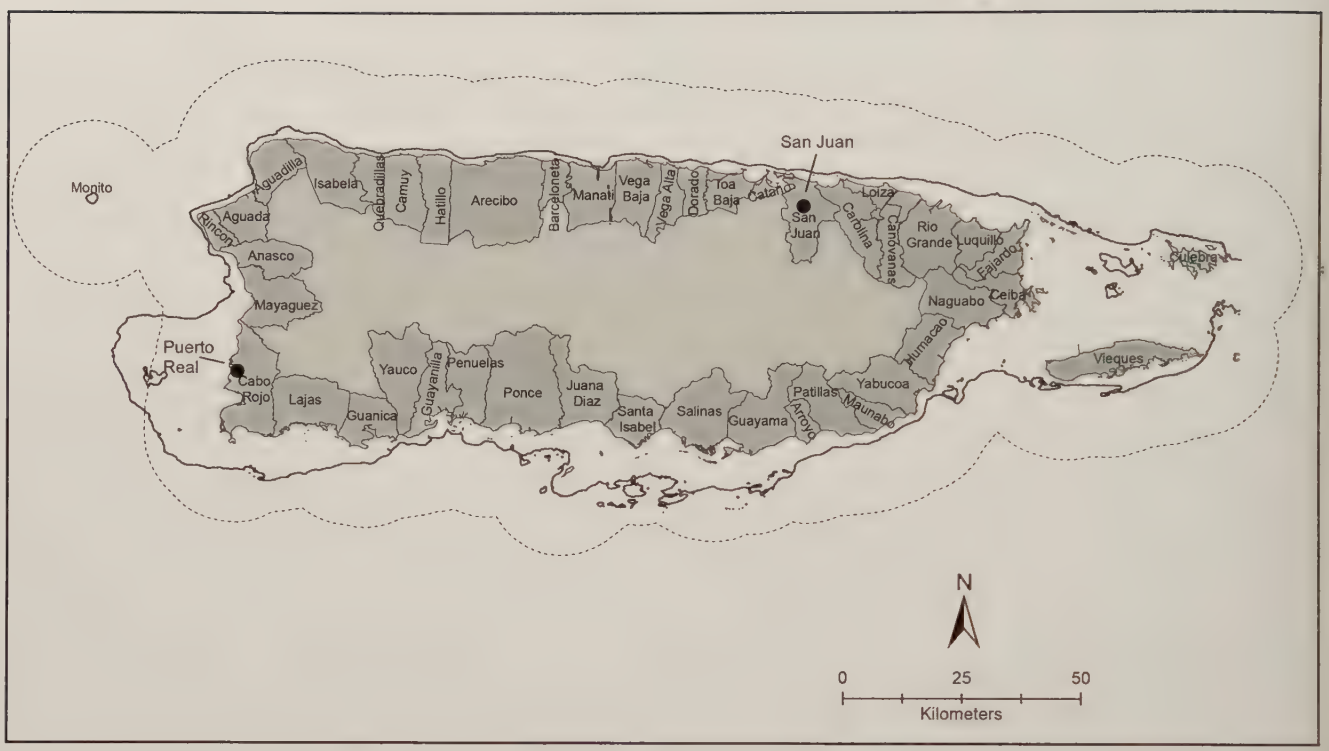

Figure 1.—Coastal municipalities in the Commonwealth Puerto Rico.

are primarily derived from hook and line (65%) and skin and scuba diving (19%)

A captain and a single deckhand (known as a "proel") run most fishing operations with the exception of dive operations, which have larger crews (Agar and Shivlani, 2016). Many fishermen have diverse livelihood portfolios that may include local work in construction and agriculture as well as temporary migrations to the United States mainland (Gutiérrez-Sánchez, 1982; Pérez, 2005; Griffith et al., 2007; Agar et al., 2020). Many also supplement their income with government transfer (welfare) payments (Griffith and Valdés-Pizzini, 2002; Pérez, 2005).

Fishing centers (known as "villas pesqueras") are places where fishermen land, process, and market fish. They may also repair and store fishing gear and equipment and socialize and exchange information with their peers (Gutiérrez-Sánchez, 1982; Valdés-Pizzini, 1990). Fishermen also sell directly to dealers, fish stores, restaurants, and hotels; a few fishermen retail their catches from their homes or peddle them to nearby communities (Valdés-Pizzini, 2011; Matos-Caraballo and Agar, 2011).

Puerto Rico's Department of Natural and Environmental Resources (DNER) and the Caribbean Fishery Management Council (CFMC) are the main fishery management agencies. DNER manages fisheries out to 9 nmi from the coast, and the CFMC manages those in federal waters, which extend from 9 to 200 nmi (Agar et al., 2019). With the exception of the deepwater snapper fishery limited entry program (i.e., cardinal, *Pristipomoides macrophthalmus*, and queen snappers), fisheries operate under a regulated open-access regime. Federal and commonwealth fishery managers use a variety of management measures, including annual catch limits (or quotas), trip limits (for queen conch), gear restrictions, seasonal and area closures, size limits, and other miscellaneous restrictions (CFMC[2]).

Methods

We conducted a rapid assessment to examine the initial socioeconomic consequences of the pandemic on small-scale fisheries between July and September 2020. The study focused on the first 6 months of 2020 (January through June) because seafood markets began to be disrupted in January 2020 when the Chinese government imposed a lockdown in the city of Wuhan. The assessment targeted seafood dealers and processors, for-hire operators, and small-scale fishermen; however, for the sake of brevity, we only discuss the results of the last group.

The sampling frame was based on the population of fishing captains who either reported landings statistics in

[2]CFMC (Caribbean Fishery Management Council). 2021. Regulations (Avail. at https://www.caribbeanfmc.com/regulations).

2018 and/or 2019 or self-identified as a fishing captain in a recently conducted post-hurricane María fishermen census. We chose this frame over one that solely relied on fishermen who reported fishery statistics because of the difficulty of identifying the population of active participants. This population is hard to sample because of post-hurricane María fishermen turnover and the diversity of livelihood strategies. These strategies may combine year-round or seasonal fishing with other wage labor opportunities, including work in the United States mainland (Griffith and Valdés-Pizzini, 2002; García-Quijano et al., 2015; Agar et al., 2020). Additionally, many fishermen continued fishing with expired licenses.

The sampling protocol required interviewers to reach out to captains by telephone, drawing from a stratified, random sample. We stratified the sample by coastal region (i.e., east, north, south, and west) to capture the impact of the pandemic on a wide range of fisheries (Fig. 1). To satisfy the requirements of the sampling protocol, interviewers were instructed to draw a replacement fisherman only if the randomly selected fisherman a) refused to participate; b) was unavailable due to illness, travel, or death; or c) could not be contacted after three separate attempts. Before starting the survey, interviewers read a script indicating that responses were voluntary and that they would be kept confidential. The script also stated that survey participants could decline to answer any questions, and that there were no direct benefits, risks, or compensation for participating in the survey. Port agents from the DNER's Fisheries Research Laboratory and contracted field assistants, mainly recent university graduates, conducted the telephone interviews.

Consistent with other regional COVID-19 impact assessments, we employed the survey instrument designed by NMFS social scientists (Benaka and Thunburg, 2021; Glazier et al., 2021); however, we slightly modified its content to ensure that some of the closed-ended questions better aligned with the local context. The survey was translated into Spanish and the data were entered into a Qualtrics[3] platform.

The survey instrument inquired about a) demographic background; b) whether fishermen were impacted by the pandemic and for how long; c) COVID-19 related factors that most affected fishing operations and its impacts on fishing activity, employment, and revenues; and d) main sources of support to cope with COVID-19 related impacts. The survey instrument is available upon request from the authors.

In total, 317 fishing captains participated in the voluntary survey. Despite the absence of compensation, only 10 respondents declined taking the survey showing a high degree of avidity. The actual response rate was 45%; however, if we ignore unreachable fishermen, then the effective response rate rises to 68%. The main reasons for the non-responses were failure to reach the fisherman after three contacts (35%), disconnected/wrong phone numbers (22%), duplicate names (21%), and missing phone numbers (19%). Approximately 28% of the respondents were from the north coast, 27% from the west coast, 26% from the east coast, and the remaining 18% from the south coast.

The study also benefited from governmental fishery statistics, print media stories, CFMC records, and interviews with key informants, who are individuals who have first-hand knowledge about the fishing industry such as fishery and fishing center managers. We used this information to gain additional insight about the impacts of the pandemic and to contextualize our findings. DNER runs the fishery statistics program which collects trip-level information on landings by species (or species groups), landing site, fishing gear used, effort expended, and dockside prices. The data collected is self-reported by the fishermen.

[3]Mention of trade names or commercial firms does not imply endorsement by the National. Marine Fisheries Service, NOAA.

Statistical Analysis Software (SAS) was used to develop commonwealth and regional (north, east, south, and west coasts) descriptive and inferential statistics.[4] We used one-way ANOVA, Kruskal-Wallis, Chi square, and Fisher tests to examine for differences among coastal regions. One-way ANOVA tests were used to examine whether there are statistically significant differences between the means of three or more independent (unrelated) groups. One-way ANOVA tests are an omnibus test in that they cannot tell which specific groups were statistically significantly different from each other, but rather that at least two of the groups were. The Kruskal-Wallis test is a non-parametric test that was used when the normality assumption of the one-way ANOVA did not hold. The Chi-squared tests were used to examine whether there was a relationship between categorical variables. The Fisher exact test is a more powerful, computationally intensive test that was used to examine relationships between variables when there were few observations or highly unequal cell distributions. To counter the effects of multiple testing we used the Bonferroni correction. Tables report p-values, but only those bolded p-values are statistically significant at the 5% level after the Bonferroni correction.

Results and Discussion

Sample Characteristics

Most of the fishing captains interviewed were males with extensive fishing experience (Table 1). Ages ranged from 19 to 96 years, averaging 54 years. Around 5% of the survey participants were 30 years old or younger, and 27% were 65 years old or older. On average, east coast fishermen were older (56 years old) and west coast fishermen younger (51

[4]The northern region extends from the municipalities of Isabella to Luquillo (Fig. 1). The eastern region runs from the municipalities of Fajardo to Maunabo, including the islands of Vieques and Culebra, and the southern region stretches from the municipalities of Patillas to Lajas. The western region extends from the municipalities of Cabo Rojo to Aguadilla.

years old). Respondents had been fishing between 1 and 76 years, averaging 27 years. Regionally, fishermen from the west coast were the most experienced (31 years) whereas those from the north coast were the least experienced (23 years).

Households were highly dependent on commercial fishing (Table 1). Seventy-three percent of the captains reported that fishing was their primary source of personal income. The proportion of respondents who stated that fishing was their primary source of income was highest on the west coast (84%) and lowest on the north coast (53%). Puerto Rican fishermen often participate in formal and informal non-fishing, wage-earning occupations such as construction, mechanical work, landscaping, and farming to supplement their fishing income.

About 60% of the captains fished mainly in commonwealth waters and another 39% fished in both commonwealth and federal waters (Table 1). Nighty-two percent of the east coast captains primarily fished in commonwealth waters whereas the majority of west coast captains (72%) fished in both federal and commonwealth waters.

Table 1.—Sample characteristics by coastal region.[1]

Item	Region				Puerto Rico total	No.
	East coast	North coast	South coast	West coast		
Number of respondents	83	89	58	87	317	317
Age (yr)	55.8 (13.2)	55.5 (14.3)	55.2 (15.2)	50.5 (13.7)	54.2 (14.1)	312
Fishing experience (yr)	26.2 (16.4)	22.8 (18.9)	26.1 (18.0)	31.3 (16.3)	26.6 (17.6)	313
Fishing main source of income (%)						
Yes	77.1	52.8	79.3	83.9	72.6	317
No	20.5	46.1	20.7	14.9	26.2	
Prefer not to answer	2.4	1.1		1.2	1.3	
Main fishing areas (%)						
Commonwealth (0- 9 nm)	91.6	60.7	62.1	26.4	59.6	317
Federal (9-200 nm)		1.1	1.7		0.6	
Both	8.4	38.2	36.2	72.4	39.4	
Prefer not to answer				1.2	0.3	

[1]Mean and standard deviation (in parentheses), unless otherwise noted.

Table 2.—Early COVID-19 related impacts on fishing operation.

Item	Region				Puerto Rico total	No.
	East coast	North coast	South coast	West coast		
Was your fishing operation affected by COVID-19? (%)						
Yes	97.6	94.4	98.3	94.3	95.9	317
No	2.4	5.6	1.7	5.8	4.1	
Did you stop fishing for any period of time due to COVID-19? (%)						
Yes	95.1	98.8	87.7	91.4	93.7	303
No	4.9	1.2	12.3	6.2	5.6	
Prefer not to answer				2.5	0.7	
Duration of fishing inactivity (%)						
Less than 1 month	23.4	8.4	12.0	7.9	12.9	286
1-3 months	48.1	31.3	52.0	46.1	43.4	
More than 3 months	18.2	55.4	34.0	22.4	32.9	
Indefinitely with plans to resume fishing	9.1	4.8	2.0	19.7	9.4	
Went out of business	1.3			1.3	0.7	
Prefer not to answer				2.6	0.7	

Main COVID-19 Disruptions

On 15 March 2020, Governor Wanda Vázquez-Garced issued Executive Order 2020-23, mandating an island-wide lockdown, a nighttime curfew, and the closure of hotels, restaurants, and other food service establishments, except for those using takeout, delivery, and drive-through.[5,6] The order also closed public and private schools and universities, all non-essential businesses and public agencies, and implemented travel restrictions. Due to the uncertainty about the designation of fishermen as essential workers, fishing ceased briefly. After the government confirmed their essential worker designation, fishing resumed to take advantage of the rest of the Lenten season, when seafood sales increase because many Christians give up meat and eat fish on Fridays. In 2020, Lent started on 26 February and ended on 9 April.

Our survey found that the majority of the fishing operations were affected by the pandemic, forcing many to interrupt their fishing activities for extended periods of time (Table 2). When we inquired about the top three COVID-19 related factors that had the largest impact on fishing operations, respondents cited the loss of seafood markets (79%), commonwealth and local government restrictions (71%), and the adoption of sanitary control and prevention measures (48%; Table 3).

In addition to the losses already suffered from the closure of restaurants and hotels following the lockdown, fishermen explained that seafood sales weakened after Lent because many of the remaining food establishments limited their menu options to "value propositions" which mainly used chicken, pork, and beef to stay in business.[7] As one fisherman from the municipality of Rincón explained, "no one is going to buy an expensive fish from a restaurant (e.g., queen snapper

[5]Executive Order 2020-23 (https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/2020-03/PR%20DeclarationofEmergency.pdf).

[6]The island-wide lockdown lasted 88 days.

[7]In April alone, 30,000 jobs were lost in the Puerto Rican leisure and hospitality sector. BLS (U.S. Bureau of Labor Statistics). 2021. Puerto Rico. (Avail. at https://www.bls.gov/regions/new-york-new-jersey/puerto_rico.htm#eag_pr.f.1, accessed 16 April 2021).

Table 3.—Top 3 COVID-19 related factors that had largest impact on fishing operation.[1]

Largest impacting factor (%)	Region				Puerto Rico total	No.	p-value
	East coast	North coast	South coast	West coast			
No seafood markets	71.1	76.4	81.0	87.4	78.9	317	0.0639
Restrictions by commonwealth and local governments	80.7	69.7	72.4	63.2	71.3	317	0.0885
Implementation of sanitary measures	80.7	38.2	58.6	20.7	48.3	317	**<0.0001**[2]
Low seafood prices	28.9	12.4	8.6	33.3	21.8	317	**0.0002**
Other	3.6	34.8	37.9	13.8	21.5	317	**<0.0001**
Instructed to stop fishing by dealer, fish receiver, processor	7.2	6.7	8.6	50.6	19.2	317	**<0.0001**
Lack of charter clients	3.6	38.2	20.7	1.2	15.8	317	**<0.0001**
Loss of crew	4.8	4.5	5.2	1.2	3.8	317	0.0069[3]
No available crew	4.8	2.3	1.7	1.2	2.5	317	0.5090[3]
Prefer not to answer	2.4			2.3	1.3	317	10.3436[3]

[1]χ^2 tests were used to test for differences among coastal regions, unless otherwise noted.
[2]Statistically significant differences after the Bonferroni correction ($p<0.05$) are shown in bold.
[3]Fisher tests were used to test for differences among coastal regions.

which retails for $40–50 a dish) to eat it out of a foam container. They want to be served in a restaurant." A DNER study, which surveyed fishermen and fish dealers between 15 March and 31 April 2020, reported additional reasons for the drop in seafood demand, including fewer consumers heading to fish stores because of COVID-19 exposure worries, time constraints, and/or travel restrictions due to the curfew and lockdown, and an uneasiness about fish retailers' adherence to COVID-19 food safety protocols.[8] This DNER study also reported that many of fish houses closed after Lent because of the slow demand and that few fishermen went out fishing because of poor weather conditions.

Table 3 shows that restrictive commonwealth and local mandates were the second most cited COVID-19 related factor impacting fishing activities. In contrast to the sluggish response of the local government following hurricanes Irma and María, the government acted swiftly to control the spread of the virus. Commonwealth and local governments implemented timely and strict lockdowns and curfews to safeguard the fragile health care system (Cruz-Correa et al., 2020). Perreira et al.[9] reported that the mass outmigration of health care professionals in the past decade left few physicians to care for Puerto Rico's aging and poor population, particularly in San Juan's metropolitan area and nearby municipalities. Perreira et al.[9] also reported that the U.S. Health Resources and Services Administration (HRSA) considered 72 of 78 commonwealth municipalities to be medically underserved.

Our study also documented that poorly enforced governmental orders caused significant angst among fishermen because they were routinely stopped by local enforcement agencies and told to return home. Fishermen would be stopped for either driving to go fishing during curfew hours or for having expired boat registrations and/or fishing licenses, which could not be renewed because government offices were closed. Hanke et al.[10] reported that many fishermen shunned nighttime fishing so they would not be stopped during curfew hours. To address these problems, DNER reached out to enforcement to remind them that fishermen were designated essential workers and also issued (fishing license and/or boat registration) waivers to allow fishermen to return to their fishing routines. Hanke et al.[10] also noted that small-scale fishermen were burdened by recreational boating and fishing restrictions because these restricted their access to public ramps and docks.

The implementation of sanitary control and prevention measures was the third most cited COVID-19 related factor that impacted fishing operations the most (Table 3). Survey participants raised the same concerns as those previously reported by the DNER study[8], namely that sales fell because of social distancing mandates that resulted in the closure of restaurants and hotels, and reduced foot traffic to seafood markets due to exposure worries, time and travel restrictions, and concerns about the quality of food safety protocols regarding COVID-19 (Fig. 2).[8] Fishermen also told us that infection concerns for oneself and loved ones sidelined many older fishermen. Port agents observed (personal communications) that few active fishermen followed face covering and social distancing guidelines because these were impracticable in small fishing vessels where fishermen spend extended periods of time in close proximity.

Noteworthy is that of the three main COVID-19 related factors reported to have had the largest impact on fishing operations, only the adoption of sanitary measures exhibited significant regional differences, suggesting that the impact of COVID-19 on seafood mar-

[8]Santiago-Soler, W. G. 2020. COVID-19 impact in Puerto Rican commercial fishers [PowerPoint slides]. Reunión del Panel Asesor de Distrito de Puerto Rico, Carib. Fish. Manage. Counc., 3-4 June.

[9]Perreira K., R. Peters, N. C. Lallemand, and S. Zuckerman. 2017. Puerto Rico's health care infrastructure assessment: site visit report. Urban Inst., Wash., D.C., 30 p. (Avail. at https://www.urban.org/research/publication/puerto-rico-health-care-infrastructure-assessment-site-visit-report).

[10]Hanke, M., P. M. Sotomayor, K. M. Torres-Figueroa, E. M. Collazo Montañez, and G. Hernández. 2020. Cambios en la actividad pesquera de Puerto Rico a raíz de la pandemia de COVID-19: Un cuestionario de pescadores comerciales. Unpubl. manuscr., Univ. Puerto Rico, Recinto de Humacao.

kets and on governmental actions were universally felt throughout Puerto Rico (Table 3). We are unclear why the adoption of sanitary measures showed marked regional disparities, especially between fishermen from the east and west coasts. Although west coast fishermen are on average younger than those from other regions it is unlikely that health concerns were sole factor driving these regional differences.

Other less cited factors that impacted their fishing operations included low seafood prices (22%), miscellaneous reasons (22%), dealer instructions to limit their catches (19%), and lack of charter clients (16%; Table 3). The relatively modest ranking of low seafood prices was somewhat unforeseen (or perhaps conflated with the loss of markets answer), but it is consistent with the findings of the DNER and Hanke et al. studies.[8, 10] In line with these studies, a CFMC member reported that villas pesqueras in Puerto Real in the municipality of Cabo Rojo did not lower the prices paid to the fishermen but rather "played with retail prices" (i.e., markups) to ensure that fish was accessible to the public, re-sellers (e.g., wholesalers, peddlers, and individuals tied to fish delivery), and to a small number of villas pesqueras, which had no or little fishing activity.[11] The impact of low seafood prices had a marked regional component probably because of the strong competition for customers, especially on the west and east coasts, which are the two most productive regions. Another reason that may explain why the impact of low prices differed across regions, is that dealer instructions to slow down fishing ("aguantar la pesca") ranked considerably higher on the west coast, which may have encouraged local fishermen to be more aggressive finding additional markets for their catches (Table 3).

The "other" category was meant to be a "catch all" option for answers not available as choices; however, fishermen mostly reiterated concerns voiced earlier. On the south coast, fishermen emphasized infection and curfew concerns, followed by worries about expired fishing licenses, soft markets, poor weather, and earthquakes. On the north coast, fishermen expressed concerns about protecting themselves and their family members, particularly those who were sick, and, to a lesser extent, issues related to the difficulties of renewing fishing license and market weakness. On the west coast, fishermen stressed contagion fears, fishing license renewal difficulties, and concerns about gear theft, whereas those on the east coast raised the problems associated with fishing license renewals and access to closed public ramps and docks. Table 3 shows that the loss of charter clients was more noticeable on the north coast probably because the many fishermen in our sample either ran or mostly likely worked as crew in charter operations. The northwest coast is an important hub for offshore and inshore fishing. The loss or unavailability of crew had minor impact on most fishing operations (Table 3).

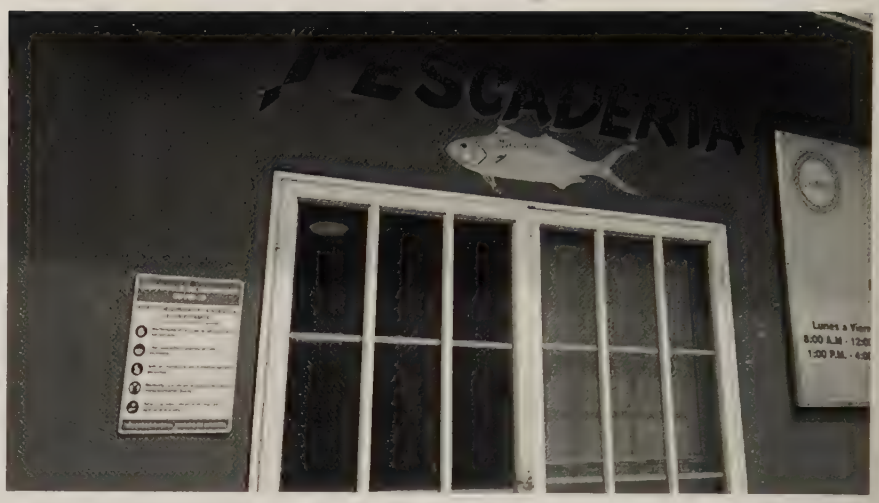

Figure 2.—COVID-19 sanitary protocol sign in villa pesquera "Jarealito" in the municipality of Arecibo. Credit: Daniel Matos-Caraballo.

Operational Responses and Obstacles

When we inquired how the pandemic had affected fishermen's normal fishing operations, even if temporary, compared to the first 6 months of the previous year (January–June 2019), the single, most common answer was that they took fewer fishing trips (83%; Table 4). Similar results were reported by the DNER and Hanke el al. studies[8,10]; however, the impact on catch volumes (per trip) was mixed. Hanke et al.[10] reported reductions of up to 50%, while the DNER study[8] stated that catch volumes were comparable to those of earlier years. A CFMC member reported that villas pesqueras in Puerto Real in the municipality of Cabo Rojo, other than setting a brief 20 lb. lobster limit per boat, did not impose explicit catch limits on their members but did require them to limit the number of trips to four per week (weekdays only) so that they could move the inventory over the weekend (wholesale, house to house, delivery and/or takeout).[11,12] She also noted that the villas pesqueras would inform their members which species were popular with consumers and how much inventory they could sell, which proved useful aligning supply and demand. Fishermen from the

[11]Caribbean Fishery Management Council. 2020. Reunión del Panel Asesor de Distrito de Puerto Rico. June 10, 2020. [Video on YouTube. https://www.youtube.com/watch?v=MWrZ5GhyC5w].

[12]The only exception to this rule was for boats that targeted queen snapper and large silk snappers, which were primarily sold to restaurants. These boats were only allowed to take 1 trip per week; however, there were no limits on the duration of the trip and how much could be landed because these species are caught in deeper waters.

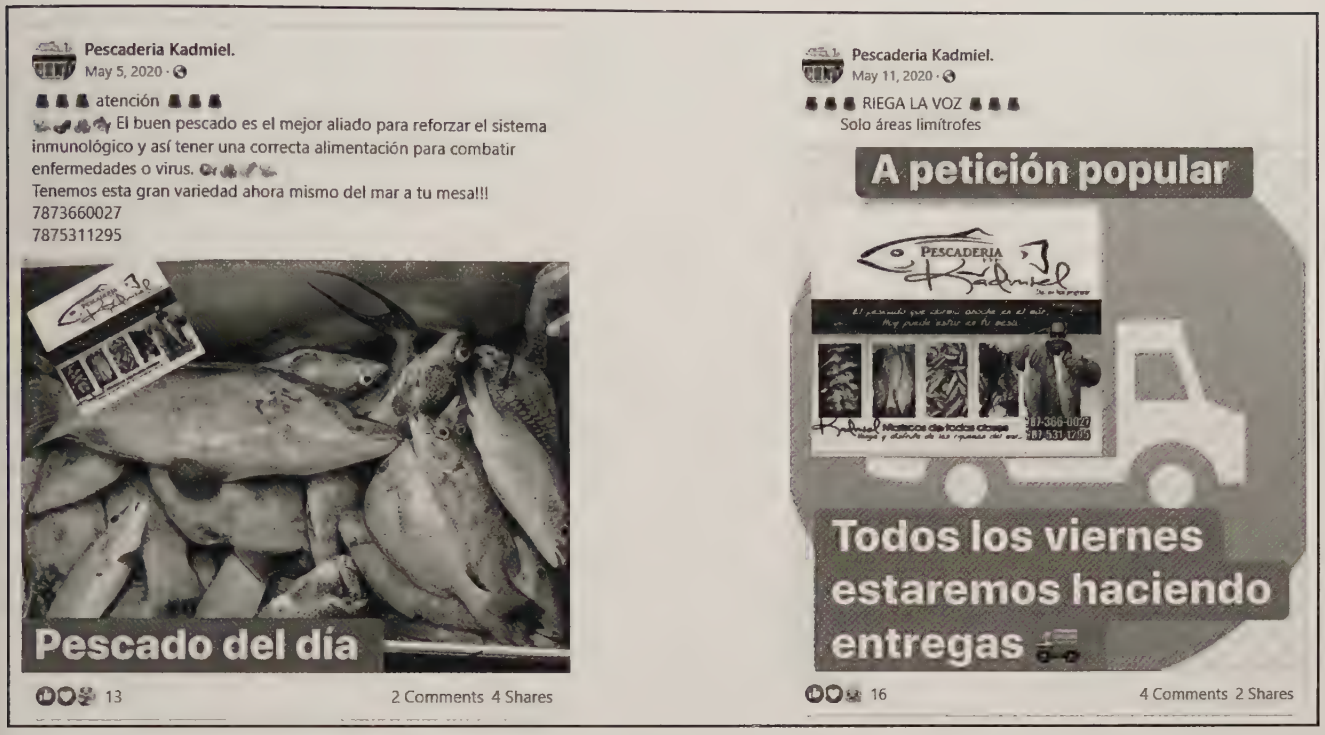
Pescaderia Kadmiel.
May 5, 2020 ·
atención
El buen pescado es el mejor aliado para reforzar el sistema inmunológico y así tener una correcta alimentación para combatir enfermedades o virus.
Tenemos esta gran variedad ahora mismo del mar a tu mesa!!!
7873660027
7875311295
Pescado del día
13
2 Comments 4 Shares
Pescaderia Kadmiel.
May 11, 2020 ·
RIEGA LA VOZ
Solo áreas limítrofes
A petición popular
Todos los viernes estaremos haciendo entregas
16
4 Comments 2 Shares

Figure 3.—Seafood marketing using social media. Credit: Carlos Joel Velázquez (Pescadería Kadmiel, Naguabo).

Table 4.—Early COVID-19 related operational responses and obstacles, even if temporary.[1]

Operational responses, even if temporary (%)	Region				Puerto Rico total	No.	p-value
	East coast	North coast	South coast	West coast			
Reduced number of trips	92.8	74.2	77.6	87.4	83.3	317	**0.0045**[2]
Other	28.9	37.1	63.8	17.2	34.4	317	**<0.0001**
Developed new markets (dealers, buyers, clients)	20.5	18.0	13.8	62.1	30.0	317	**<0.0001**
Difficulties obtaining other supplies	38.6	20.2	19.0	5.8	20.8	317	**<0.0001**
Difficulties obtaining bait	34.9	15.7	10.3	10.3	18.3	317	**<0.0001**
Shifted to other fisheries	12.1	3.4	1.7	4.6	5.7	317	0.0458[3]
Prefer not to answer	1.2	2.3		2.3	1.6	317	0.8154[3]

[1]χ^2 tests were used to test for differences among coastal regions, unless otherwise noted.
[2]Statistically significant differences after the Bonferroni correction ($p<0.05$) are shown in bold.
[3]Fisher tests were used to test for differences among coastal regions.

east and west coasts reported the highest reductions in fishing effort most likely because they are the most productive regions in Puerto Rico.

The pandemic not only affected governmental policies but also the food purchasing and consumption behavior of consumers. Consumers increased their use of delivery services, prepared more home cooked meals, and sought healthier food choices as result of shelter in place orders and also to reduce their chances of contracting COVID-19. Our survey found that 30% of the fishermen polled revamped their marketing strategies to cater to these emerging opportunities. One fisherman from the municipality of Rincón explained that the pandemic forced them to reinvent ourselves ("la pandemic nos obligo a reinventarnos"). Villas pesqueras, fish stores, and entrepreneurial fishermen became more active on social media using Facebook and Instagram to post information on species availability, prices, health benefits, and delivery and pick-up options, including contactless alternatives (Fig. 3). Many processed their catches (e.g., scaling, filleting, and "steaking") to add value and incorporated additional offerings such as seafood and land crab turnovers ("empanillas de mariscos y jueyes") to make their products consumer friendly.[13]

Only 6% of the survey participants shifted to other fisheries (Table 4). We heard of a small number of fish-

[13]Notiséis 360. 2020. Pescadores se reinventan para mantener la industria activa. 16 April 2020. [Video on YouTube. https://www.youtube.com/watch?v=1FnuM6_w91I].

ermen who switched gears (e.g., from hook and line to nets) to catch low value nearshore species (e.g., sardines, scads, and jacks) for human consumption, and of others that kept the same gear (e.g., hook and line) but targeted more economical species (e.g., from silk snapper to little tunny, *Euthynnus alletteratus*). A chef from Arecibo observed that the pandemic had forced him to switch from selling 2–3 lb. whole fish (e.g., silk, queen, and yellowtail snappers) to fish fillets (e.g., dolphinfish and wahoo, *Acanthocybium solandri*) because the latter species were more practical and profitable alternatives for takeout (Hanke et al.[10]). The Hanke et al. study[10] also found that most fishermen did not alter the composition of their catches, with the exception of those who fished at night (e.g., yellowtail snapper and king mackerel, *Scomberomorus cavalla*) because of curfew hassles.

In addition to overhauling their marketing practices, fishermen had to deal with a number of logistical obstacles that hampered their fishing operations. Among the top hurdles were "other" (34%) and difficulties procuring supplies (21%) and bait (18%; Table 4). In the "other" or catch-all category, fishermen from the south coast reported that production had fallen because of weak markets, earthquakes, fishing license renewal difficulties, and fishing supply shortages (e.g., rope and wire for traps, compressed air for scuba tanks). On the north coast, fishermen stated that they took fewer trips because of contagion concerns, weak demand, and complications in renewing their fishing licenses. A handful reported difficulties securing fishing supplies. East coast fishermen underscored the loss of markets and, to a lesser extent, difficulties renewing their fishing licenses, while west coast fishermen mainly stressed the loss of markets.

Supplies and bait procurement hurdles ranked high on the east coast (39% and 35%, respectively) relative to the other regions probably because a higher percentage of east coast fishermen launch from marinas (e.g., Puerto Del Rey) and public ramps (e.g., Las Croabas). The island-wide closure of marinas and public ramps to recreational boating and fishing (but not to commercial fishing) resulted in fewer fishing supply stores remaining open. Marinas could only sell fuel to government and commercial fishing vessels. Hanke et al.[10] also found that the closure of fishery-support businesses (e.g., mechanics), fishing supply and equipment shortages (e.g., spare parts, bait, etc.), and the loss of cold storage options forced many to stop fishing. In addition, most, if not all, surf and dive shops were closed, limiting air supply options to scuba diving operations (Hanke et al.[14]). Many fish stores were uncertain how to implement sanitary protocols which further slowed down the fishing activity.

Production, Economic, and Employment Losses

With COVID-19 impacting both the demand and supply of seafood, the local fishing activity fell dramatically. Ninety-four percent of the respondents were forced to interrupt their fishing activities (Table 2). One third of the fishermen polled said that they paused for more than 3 months and another 9% said that they stopped indefinitely but planned to resume fishing. Less than 1% reported that they went out of business (Table 2).

Fishermen reported that their fishing activity was 36%, relative to June 2019 levels. Regionally, the west coast was the hardest hit (26%), followed by the south (39%), east (40%), and north (42%) coasts (results not in tables). The marked regional differences are probably tied to declining catches of species that were largely sold to restaurants and hotels (e.g., queen and silk snappers) and to the tremors and aftershocks (December 2019–January 2020) that caused extensive structural damage along the southwest coast.

Fishermen's earnings also declined because these are tied to the success of the fishing operation. Rather than being paid a wage, fishermen receive a share of the net returns. Share (or lay) arrangements are widely used around the world to spread the risk of fishing and to foster and reward productivity and teamwork (Acheson, 1981; Gutiérrez-Sánchez, 1982; Agar et al., 2017). Many fishermen also lost nonfishing, wage labor opportunities because of the lockdown and social distancing mandates. Eighty-seven percent of respondents said that their fishing revenue fell since January 2020 (Table 5).

Fishermen reported that, on average, their revenues fell by 65% relative to the first 6 months (January–June) of 2019, which translates to $6,900 ($5,000 median; Table 5). The severity of the losses varied regionally, ranging from $5,700 on the south coast to $8,600 on the west coast. Hanke et al.[10] estimated that Puerto Rican fishermen lost $8,300 in fishing revenues during the first 6 months of the pandemic (Table 5). Additionally, Hanke et al.[10] note that fishermen lost an extra $1,900 in gear damages and losses—mainly from passive (or soaking) gears such as traps, gillnets, and trammel nets—because governmental restrictions prevented their timely retrieval.

Fishermen also mentioned that their income suffered because of poaching. A fisherman from the municipality of Rincón reported that large numbers of poachers in this area were having a "field day" ("Los furtivos se hicieron su Agosto"[15]), many selling their illegal catches unfazed in social media. Stokes et al. (2020) also reported an increase in illegal fishing in nature reserves around San Juan.

Due to uncertain recovery prospects, 25% of the respondents said they laid off crew. On average, they reduced the size of their crew by one worker (Table 5). However, the impact of COVID-19 on the livelihoods of the crew was probably more pronounced because many crew members, who preferred to work full time, ended up

[14]Hanke, M. Caribbean Fishery Management Council, San Juan, Puerto Rico, personal commun., 7 April 2021.

[15]This Spanish expression refers to the benefits of a bountiful harvest which take place during summer months.

Table 5.—Early COVID-19 related impacts on revenues and employment.[1]

Item	Region				Puerto Rico total	No.	p-value
	East coast	North coast	South coast	West coast			
Revenue changes since January 2020 (%)							
Increased		1.2			0.3	303	<0.0001[2]
Decreased	95.1	78.6	79.0	95.1	87.5		
Stayed the same	4.9	20.2	21.1	2.5	11.6		
Prefer not to answer				2.5	0.7		
Revenue decrease relative to January-June of 2019 ($)	6,440.6 (5,657.3)	6,312.5 (7,427.6)	5,706.7 (4,048.8)	8,595.5 (9,543.7)	6,909.4 (7,155.7)	222	0.7482[3]
Current crew size on all vessels (excluding self)	1.7	1.2 (0.9)	1.1 (0.8)	1.0 (0.7)	1.2 (0.6)	297 (0.8)	**<0.0001**[3]
Fewer employees	1.4 (0.6)	0.8 (0.8)	0.7 (0.6)	1.0 (0)	1.0 (0.7)	75	**0.0105**[3]

[1]Mean and standard deviation (in parentheses), unless otherwise noted.
[2]Fisher tests were used to test for differences among coastal regions.
[3]Kruskal-Wallis tests were used to test for differences among coastal regions.
Statistically significant differences are shown in bold.

Table 6.—Main coping strategies that helped to deal with the early impacts of COVID-19.[1]

Factors (%)	Region				Puerto Rico total	Most Important	No.	p-value
	East coast	North coast	South coast	West coast				
Family and/or friends	49.4	53.9	46.6	69.0	55.5	90	317	0.0222
Personal savings	71.1	21.4	32.8	64.4	48.3	84	317	**<0.0001**
Government assistance	37.4	25.8	41.4	57.5	40.4	74	317	**0.0003**
Other	1.2	28.1	19.0	3.5	12.6	28	317	**<0.0001**
Church, community groups, etc.	25.3	2.3	5.2	6.9	10.1	10	317	**<0.0001**
Fishing associations, cooperatives	1.2	3.4	6.9	4.6	3.8	5	317	0.3344[2]
Prefer not to answer	1.2	3.4	1.7	3.5	2.5	4	317	0.8338[2]
Crew and/or employees	3.6				1.0		317	0.0233[2]

[1]χ^2 tests were used to test for differences among coastal regions, unless otherwise noted.
[2]Fisher tests were used to test for differences among coastal regions.
Statistically significant differences after the Bonferroni correction ($p<0.05$) are shown in bold.

working on a part-time basis. Also, as noted earlier, many might have missed out on non-fishing employment opportunities due to the lockdown. Key informants noted that Coronavirus Aid, Relief, and Economic Security (CARES) Act funds, which began to be dispersed in May 2020, provided much needed relief to the sector; however, some wondered if the unemployment benefits discouraged many from returning to work.[16]

The CARES Act created a federal package to provide economic relief to workers, families, businesses, and communities to protect them from the health and economic impacts of the pandemic. Among other things, it established the Pandemic Unemployment Assistance (PUA) program, which provided comparable unemployment benefits to unemployed workers who would not normally be eligible, such as self-employed workers and independent contractors. It also added a $600 supplement to state-paid unemployment compensation for those who already qualified for up to 4 months, which increased the current weekly unemployment compensation of $190 to a maximum of $790 weekly. To place these figures in context, Puerto Rico's minimum wage is $7.25 per hour, which translates to $290 per week. In addition, the Act extended unemployment compensation by 13 weeks beyond the eligibility time provided under current law, which was 26 weeks, until 31 December 2020. The Act also provided direct payments (stimulus checks) based on income and household size. Individuals who earned $75,000 in adjusted gross income or less received direct payments of $1,200 each, whereas married couples who earned up to $150,000 received $2,400, with an additional $500 for each child.

Coping Strategies

Finally, we asked fishermen which were the main coping strategies that they relied on to weather the impacts of the pandemic. Among the most popular ones were the support of family and friends (56%), personal savings (48%), and access to public assistance (40%; Table 6). Other less frequently used coping strategies listed in Table 6 include "other" (13%), support from churches and community groups (10%), and assistance from fishing associations (4%). Less than 1% said that their crew or employees had helped them cope with the effects of COVID-19. In the "other" (or catch-

[16]Coronavirus Aid, Relief, and Economic Security (CARES) Act. Public Law 116-136. 2020.

Table 7.—Main sources of financial assistance during the early days of the COVID-19 pandemic.[1]

Sources (%)	Region				Puerto Rico total	No.	p-value
	East coast	North coast	South coast	West coast			
Federal stimulus check	69.9	78.7	74.1	78.2	75.4	317	0.5167
Unemployment benefits	34.9	44.9	41.4	56.3	44.8	317	0.0419
Other	25.3	31.5	27.6	6.9	22.4	317	**0.0005**
No assistance requested	7.2	2.3	5.2	8.1	5.7	317	0.3093[2]
Prefer not to answer	2.4	3.4	1.7	2.3	2.5	317	1.0000[2]
Private bank loans/personal line of credit	2.4	3.4			1.6	317	0.1825[2]
Paycheck Protection Program			5.2		1.0	317	**0.0059**[2]
SBA loans		1.1			0.3	317	1.000[2]

[1]χ^2 tests were used to test for differences among coastal regions, unless otherwise noted.
[2]Fisher tests were used to test for differences among coastal regions.
Statistically significant differences after the Bonferroni correction ($p<0.05$) are shown in bold.

all) category, fishermen identified social security and/or pension benefits, accessing food stamps, and non-fishing employment.

When asked to rank the most helpful coping strategy, 28% mentioned the support of family and friends, 26% stated personal finances, and another 23% said government assistance. Like in earlier crises, fishermen turned to family and friends for emotional and financial support underscoring the importance of social capital during times of need.

Social capital is a broad concept that describes the strength of social ties, the degree of trust, and norms of reciprocity that facilitate collaboration among individuals and groups of individuals (Grafton, 2005). A growing literature indicates that communities with high levels of social capital better handled recent outbreaks (SARS, Ebola, Zika, and early COVID) (Makridis and Wu, 2021).

A fisherman from the municipality of Rincón recounted the various ways that fishermen helped each other during the pandemic. He mentioned that some would loan money to be paid later or deducted from future fish sales (e.g., instead of getting paid say $8/lb, the borrower would receive $7/lb until the loan was repaid), while others would lend bait and supplies to be returned later. We also learned of individuals who would help out fishermen by purchasing their catches, and then they would re-sell them. This helped fishermen because it provided them with another outlet for their catches.

In addition to the support of family and friends, fishermen stressed the importance of government assistance because many lived day-to-day and could not find non-fishing work because of social distancing mandates. Moreover, many had informal contractual arrangements and were uncertain about a rapid recovery. Among the most popular government programs that fishermen could access since January 2020 were federal stimulus checks (75%), unemployment benefits (45%), and "other" (22%; Table 7). Under the "other" category, many identified federal stimulus checks and pandemic unemployment benefits and added social security and pension benefits, municipal assistance, small business incentives, and occasional odd jobs. Less than 1% received help from the Paycheck Protection Program, which helped small businesses keep employees on their payrolls and/or bring back furloughed or laid off employees. Six percent of the respondents stated that they did not seek assistance.

It is noteworthy that many of the coping strategies used were similar to those employed to recover from the havoc of hurricanes María and Irma, with the exception of migrating to the continental United States. Agar et al. (2020) report that the support of family and friends (53%), personal finances and labor (45%), and government assistance (i.e., 33% for food stamps and 14% for disaster unemployment assistance) were the main coping strategies used by fishermen to rebuild their livelihoods following the hurricanes. Also, it is important to mention that social distancing measures and mobility restrictions disrupted the normal flow of support from formal networks and employees. Relative to the pre-pandemic times, the standing of religious, community, and non-governmental organizations fell (e.g., churches, 15%; community groups, 13%; and NGOs, 7%, post-María vs. 10% during the pandemic) and employees (5% post-María vs. 1% during the pandemic), underscoring the importance of having universal social safety nets during crises, particularly health crises.

Conclusions

This rapid appraisal of the immediate socioeconomic impacts of COVID-19 found that the loss of seafood markets mostly in hospitality and leisure sectors, strict commonwealth and local governmental restrictions (lockdowns, curfews), and the adoption of sanitary control and prevention measures (face covering and social distancing requirements) were the main factors that disrupted the livelihoods of Puerto Rican fishermen. These factors drove most fishermen to interrupt their fishing activities.

Preliminary fishery statistics show that reported landings and dockside revenues fell by 40% and 51%, respectively, relative to the first 6 months of 2019; however, fishermen told us that their fishing revenues had declined by an average of 65% during the same period. Fishermen also reported losing, on average, $6,900 relative to the first 6 months of 2019. One in four fishing captains laid off one crewmember.

The study also documented that the support of family and friends, personal savings, and social protection programs (unemployment benefits, federal stimulus checks) were main factors that helped fishermen withstand the early impacts of the pandemic. Seventy-six percent of the respondents benefited from the federal stimulus checks, 45% received unemployment benefits, and less than 1% participated in the Paycheck Protection Program suggesting that the latter program was the least helpful providing timely, short-term relief. An encouraging aspect of the pandemic was that many fishermen were able to find innovative ways to market their catches. To eke out a living some turned to increasing their use of social media while others returned to selling from roadside stands and house to house.

As of March 2021, preliminary fishery statistics show landings and dockside revenues increasing after this initial socioeconomic appraisal; however, it is too early to tell the course, duration, and full consequences of the pandemic, especially among vulnerable fishermen. Periodic rapid socioeconomic assessments such as this one can be useful tools to monitor unfolding ground conditions, to understand the far-reaching impacts of the pandemic, and to provide insights into how to better respond to future crises.

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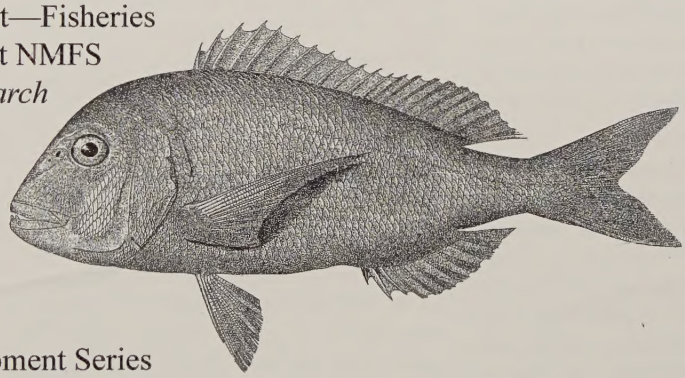

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The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to the *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700 (available from the SPO website).

Manuscripts must be double-spaced throughout, and a complete manuscript normally includes a title page, a short abstract, text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

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Keep titles, headings, subheadings, and the abstract short and clear. Because abstracts are circulated by abstracting agencies, it is important that they represent the research clearly and concisely. Headings within each section must be short, reflect a logical sequence, and follow the rules of multiple subdivision (i.e., there can be no subdivision without at least two items).

Style

The entire text should be intelligible to interdisciplinary readers; therefore, all acronyms, abbreviations, and technical terms should be spelled out the first time they are mentioned. The scientific names of species must be written out the first time they are mentioned; subsequent mention of scientific names may be abbreviated. Follow the U.S. Government Printing Office Style Manual (2008 ed.) and the Scientific Style and Format: the CSE Manual for Authors, Editors, and Publishers (2014, 8th ed.) published by the Council of Science Editors.for editorial style, and the most current issue of the American Fisheries Society's Common and Scientific Names of Fishes from the United States and Canada for fish nomenclature. Only journal titles, scientific names (genera and species), and vessel names should be italicized. Dates should be written as follows: 11 November 2013. Measurements should be expressed in metric units, e.g., metric tons as (t); other equivalent units may also be listed in parenthesis. Common abbreviations and symbols such as mm, m, g. ml, mg, and °C (without periods) may be used with numerals. The numeral one (1) should be typed as a one, not as a lower-case el (l). Write out the numbers zero through nine unless they form part of measurement units (e.g., nine fish but 9 mm).

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Tables should be printed separately and double-spaced. Tables should not be excessive in size and must be cited in numerical order in the text. Headings should be short but ample enough to allow the table to be intelligible on its own. All unusual symbols must be explained in the table heading. Other incidental comments may be footnoted with Arabic numerals. Because tables are typeset, they need only be submitted typed and formatted, with double-spaced legends. Zeros should precede all decimal points for values less than one. Table headings and format should be consistent; do not use vertical rules.

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